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(54) Title: USE OF CSAID TM COMPOUNDS FOR THE MANAGEMENT OF UTERINE CONTRACTIONS			
(57) Abstract <p>The present invention is to the novel use of a cytokine inhibitor for the prophylactic treatment, or management of excessive, undesired or inappropriate uterine activity, such as contractions, in a mammal in need thereof.</p>			

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Use of CSAID™ Compounds for the Management of Uterine Contractions

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FIELD OF THE INVENTION

The present invention relates to the treatment of inappropriate, excessive or undesirable uterine contractions, in a mammal.

10 BACKGROUND OF THE INVENTION

Preterm labour is of major concern to both obstetricians and neonatologists. It affects approximately 10% of pregnancies and results in 30% of long term neonatal handicap and 85% of perinatal deaths. The pathogenesis of preterm labour is incompletely understood at present, it is therefore difficult
15 to both predict and treat effectively. The underlying biochemical pathways involved in the initiation of parturition have not yet been fully elucidated. There are clear links between inflammatory processes and activation of the immune system in the maternal decidua. Prostaglandins, which have a well documented role in the initiation of labour, (Mitchell, MD., (1984) *Journal of Developmental*
20 *Physiology*, **6**, 107-118) and the inflammatory cytokines (Mitchell, MD., et al. (1993) *Clinical Obs. and Gynaecol*, **3**, 553-575) have therefore both been implicated in the pathogenesis of labour. Interleukin-1 β (IL-1 β) has been demonstrated to be the pivotal cytokine in the biochemical pathway leading to labour (Mitchell, MD., et al. (1993), *supra*). It has been shown to directly
25 stimulate the production of prostaglandins which are the terminal products of the inflammatory response and direct initiators of labour (Romero, R., et al. (1992) *Am. J. Reprod. Immunol*, **33**, 117-123; and Kent A.S.H., et al. (1993) *Prostaglandins* **46**, 51-59). Levels of IL-1 β have been shown to rise following stimulation with bacterial endotoxin (Romero, R., et al. (1989) *Am. J. Obstet and Gynaecol.*, **160**, 1117) which implies a mediating role for this cytokine in
30 the induction of labour in the presence of infection.

The production of prostaglandins is under the influence of two enzymes, phospholipase A2 and cyclo-oxygenase (COX) alternatively known as prostaglandin H synthase. COX has been found to be present in two forms;
35 type-1 COX is the constitutive form of the enzyme present in all tissues. Type-2 COX is the inducible form of the enzyme that has been shown to be up-regulated near term (Macchia L., et al. (1997) *Biochemical and Biophysical Research*

Communications, 233, 496-501). IL-1 β is able to increase the production of COX-2 in amnion (Trautman M.S., et al. (1996) *Placenta*, 17, 239-245).

By modulating the production of prostaglandin E₂ (PGE₂) the contractile activity of the uterus may be controlled. Tocolytic agents that completely suppress contractions are not yet available. There has been very little recent progress in the therapeutic modalities available to treat preterm labour. Currently a therapeutic cocktail consisting of betasypathomimetics, Non-Steroidal Anti-inflammatory Drugs (NSAID's), and oxytocin antagonists is used to try and suppress unwanted uterine activity.

The therapeutic cocktail does not fully address the management of preterm labor in patients, therefore a need still exists to find suitable small molecule inhibitors which will help modulate the contractile activity of the uterus in a mammal in need thereof.

SUMMARY OF THE INVENTION

The present invention is to the novel use of a cytokine inhibitor for the prophylactic treatment or management of excessive, undesired or inappropriate uterine activity in a mammal, which method comprises administering to said mammal an effective amount of a compound which inhibits the production, transcription or translation of a cytokine. Preferably, the cytokine is inhibited by inhibition of the kinase CSBP/p38/RK.

The preferred compounds for use as cytokine inhibitors are those compounds of Formula (I) as noted herein. The preferred method of inhibition is the inhibition of the CSBP/p38/RK kinase pathway.

DETAILED DESCRIPTION OF THE INVENTION

The current application teaches the novel finding that CSAID™ compounds, i.e. compounds that block cytokine production, can be a therapeutically effective agent in modulating uterine contractile activity. Such modulation will help treat preterm labour in patients in need thereof.

The present invention is to the novel use of a cytokine inhibitor, in particular that of cytokine CSBP/p38, for the prophylactic treatment or management of excessive, undesired or inappropriate uterine activity in a mammal.

As noted above, by modulating the production of prostaglandin E₂ (PGE₂) the contractile activity of the uterus may be controlled. Tocolytic agents

that completely suppress contractions are not yet available and there has been very little recent progress in the therapeutic modalities available to treat preterm labour. The current treatment for preterm labour is a therapeutic cocktail consisting of betasymphomimetics, Non-Steroidal Anti-inflammatory Drugs (NSAID's), and oxytocin antagonists. This cocktail is used to try and suppress unwanted uterine activity.

PGE₂ production by fetal membranes has been shown to be inhibited by the use of NSAID's. The efficacy in controlling uterine activity is however dependent on the specificity of the agent used and the treatments are not without their side-effects. It has now been found that small molecule inhibitors which act on cytokine synthesis may also have a similar inhibitory effect on the production PGE₂ by inhibiting cytokine driven prostaglandin production and could therefore be useful in the treatment and prevention of preterm labour. Therefore, another aspect of the present invention is the use of cytokine inhibitors of the p38/CSPB/RK pathway in the treatment of both preterm and term labour.

As will be demonstrated herein in the Example section, the CSAID™ compound SKF86002 has effectively been used to modulate prostaglandin and interleukin production from gestational tissues. The compound SKF 86002 has previously been shown to decrease the production of IL-1β from lipopolysaccharide (LPS) stimulated isolated human macrophages (Perregaux D. G., et al. (1995) *Molecular pharmacology*, 48, 433-442) and the production of prostaglandin H synthase from rat basophilic leukaemic cells (Griswold D.E., et al. (1987) *Biochemical Pharmacology*, 36, 3463-3470).

The term "inappropriate uterine activity" as used herein includes, but is not limited to, diseases which are characterized by the presence of unwanted or excessive uterine activity prior to the completion of normal gestational period in a mammal. In the case of a human, for instance, this would be approximately a 40 week gestation.

The term "excessive or increased uterine activity" as used herein is characterized by the presence of abnormal uterine action during labour. Abnormal uterine action during labour is characterized by the excessive frequency, amplitude or duration of uterine contractions.

The term "pre-term labour" as used herein refers to the onset of labour before 37 weeks gestation. However, it is recognized that pre-term labour is a complex syndrome due

to many aetiological factors. See for instance, Romero, et al., Ann NY Acad. Sci., 734, page 414 (1994).

Labour and pre-term labour are characterized by the presence of 1)
sustained uterine contractions; 2) dilatation of the cervix; and 3) rupture of the
5 fetal membranes

All three components of labour are mediated in part by the action of
inflammatory cytokines, consequently use of a CSBP inhibitor would be of use
in all these areas.

In particular, dilatation, or ripening of the cervix is affected by the
10 reorganization of collagen bundles in the cervix. This is believed to be under the
control of the enzyme collagenase, produced by neutrophils (Osmers, et al.,
American Journal of Obstetrics & Gynecology, 166, pp 1455-1460 (1992)).
Neutrophils migrate into the cervix from the surrounding tissues under the
influence of chemotactic inflammatory cytokines such as IL-8. They are then
15 stimulated by IL-8 to release collagenase which breaks down the collagen
bundles in the cervix. IL-8 has also been shown to soften the cervix after topical
application. See, Chwalisz, et al., Human Reproduction, 9, pp 2173-2181
(1994); and El Maradny et al., American Journal of Obstetrics & Gynecology,
171, pp 77-83 (1994). Therefore, use of a CSBP inhibitor should inhibit
20 unwanted cervical ripening in a mammal.

In preterm rupture of the fetal membrane (PROM) there is significant
evidence which implicates infection and inflammation in the pathogenesis of
fetal membrane rupture (French et al., Seminars in Perinatology, 20 pp 344-368
(1996)). Proteases produced in response to infection have been shown to be
25 involved in a reduction in fetal membrane tensile strength (McGregor, et al.,
Obstet and Gynceol, 69, pp 167-174 (1987)). These proteases are under the
influence of inflammatory cytokines such as IL-1 α and IL-1 β , and TNF- α
(Woessner, J. FASEB J, 5, pp 2145-2154 (1991)). An inhibitor of these
cytokines, such as CSAIDTM inhibitor, would therefore be able to prevent the
30 unwanted rupture of the fetal membranes by preventing the release of
inflammatory cytokines which stimulate the release of proteases, etc., which in
turn destroy the integrity of the fetal membranes.

Eclampsia and pre-eclampsia are thought to result from the defective
penetration of maternal blood vessels (the spiral arteries) into the trophoblast.
35 Inflammatory cytokines are important in mediating this process. Many studies
have implicated a variety of cytokine in the pathogenesis of pre-eclampsia. IL-4
has been shown to be elevated in the sera of pre-eclamptic women (Omu-Ae et

al., Nutrition, 11(5Suppl), pp 688-91 (1995 -Sep-Oct). Thus, pre-eclampsia/intrauterine dystrophy is characterized by reduction of some cytokines within the amniotic fluid compartment and concomitant reactive augmentations of other cytokines within the maternal and fetal organism. Stallmach et al., Reprod-Fertil-Dev. 1995; 7(6): 1573-80 (1995). IL-6 levels have also been shown to be increased in pre-eclamptic patients (Greer et al., Obstet-Gynecol., 84(6) (1994). A CSAID™ inhibitor, may therefore favourably modify the cytokine profile in pre-eclamptic and eclamptic patients by decreasing the severity of the disease.

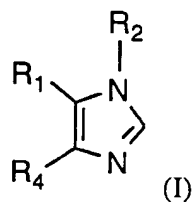
Other cytokine inhibitory compounds for use in the present invention include, but are not limited to, those described in USSN 08/091,491, published as WO95/02575; WO95/02591; US 5,593,992; US 5,663,334; US 5,670,527; WO96/21452; WO96/21654; US 5,658,903 and WO96/40143; US 5,739,143; WO96/21654; WO93/14081; US Patent 5,656,644; USSN 08/095,234; US 5,686,455; US 5,559,137; US 5,656,644 and WO95/03297; USSN 08/481,671; WO97/25048; WO97/25047; US 5,756,499 and WO97/25045; US 5,716,955 and WO97/25046; WO97/33883; WO92/10190; WO92/10498; WO98/06715; WO93/14082; WO95/13067; WO95/31451; WO 98/07425; PCT/US98/12387; WO97/05877; PCT/US98/12828; PCT/US98/13808; PCT/US97/23638; USSN 60/068,178; USSN 60/061351; WO92/12154; EP 0531901; US 5,670,503 and WO94/19350; WO97/05878; WO97/05877; WO97/05878; WO97/16441; WO97/16426; WO97/12876; US 5,717,100; WO97/45412; WO97/36587; and WO97/16442. Each of these references are incorporated by reference herein in their entirety.

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Preferred compounds for use as cytokine inhibitors are those compounds of Formula (I) as noted herein. Synthetic chemistry and methods of pharmaceutical formulations thereof are also contained within each noted patent application. A description of the assay for inhibition of the cytokine specific binding protein (CSBP) is also found in WO95/07922, whose disclosure is incorporated by reference in its entirety.

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A preferred group of compounds for use herein are those compounds of the formula (I):



wherein:

R₁ is a pyrid-4-yl, pyrimidin-4-yl, pyridazin-4-yl, 1,2,4-triazin-5-yl, quinol-4-yl, isoquinoliny, quinazolin-4-yl, 1-imidazolyl or 1-benzimidazolyl ring, which ring is optionally substituted independently one to three times with Y, NHR_a, optionally substituted C₁₋₄ alkyl, halogen, hydroxyl, optionally substituted C₁₋₄ alkoxy, optionally substituted C₁₋₄ alkylthio, C₁₋₄ alkylsulfinyl, CH₂OR₁₂, amino, mono and di-C₁₋₆ alkyl substituted amino, or N(R₁₀)C(O)R_b;

Y is O-R_a;

R₄ is phenyl, naphth-1-yl or naphth-2-yl, or heteroaryl, which is optionally substituted by one or two substituents, each of which is independently selected, and which, for a 4-phenyl, 4-naphth-1-yl, 5-naphth-2-yl or 6-naphth-2-yl substituent, is halogen, cyano, nitro, C(Z)NR₇R₁₇, C(Z)OR₁₆, (CR₁₀R₂₀)_vCOR₁₂, SR₅, SOR₅, OR₁₂, halo-substituted-C₁₋₄ alkyl, C₁₋₄ alkyl, ZC(Z)R₁₂, NR₁₀C(Z)R₁₆, or (CR₁₀R₂₀)_vNR₁₀R₂₀, and which, for other positions of substitution, is halogen, cyano, C(Z)NR₁₃R₁₄, C(Z)OR₃, (CR₁₀R₂₀)_mCOR₃, S(O)_mR₃, OR₃, halo-substituted-C₁₋₄ alkyl, C₁₋₄ alkyl, (CR₁₀R₂₀)_mNR₁₀C(Z)R₃, NR₁₀S(O)_mR₈, NR₁₀S(O)_mNR₇R₁₇, ZC(Z)R₃ or (CR₁₀R₂₀)_mNR₁₃R₁₄;

v is 0, or an integer having a value of 1 or 2;

n is an integer having a value of 1 to 10;

n' is 0, or an integer having a value of 1 to 10;

m is 0, or an integer having a value of 1 or 2;

m' is an integer having a value of 1 or 2,

m" is 0, or an integer having a value of 1 to 5;

R₂ is hydrogen, (CR₁₀R₂₀)_nOR₉, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, C₁₋₁₀ alkyl, halo-substituted C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₂₋₁₀ alkynyl, C₃₋₇ cycloalkyl, C₃₋₇ cycloalkylC₁₋₁₀ alkyl, C₅₋₇ cycloalkenyl, C₅₋₇ cycloalkenylC₁₋₁₀ alkyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl, heteroarylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nOR₁₁,

(CR₁₀R₂₀)_nS(O)_mR₁₈, (CR₁₀R₂₀)_nNHS(O)₂R₁₈, (CR₁₀R₂₀)_nNR₁₃R₁₄,

(CR₁₀R₂₀)_nNO₂, (CR₁₀R₂₀)_nCN, (CR₁₀R₂₀)_nSO₂R₁₈,

(CR₁₀R₂₀)_nS(O)_mNR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)R₁₁, (CR₁₀R₂₀)_nOC(Z)R₁₁,

(CR₁₀R₂₀)_nC(Z)OR₁₁, (CR₁₀R₂₀)_nC(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)NR₁₁OR₉,

(CR₁₀R₂₀)_nNR₁₀C(Z)R₁₁, (CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄,

(CR₁₀R₂₀)_nN(OR₆)C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nN(OR₆)C(Z)R₁₁,

(CR₁₀R₂₀)_nC(=NOR₆)R₁₁, (CR₁₀R₂₀)_nNR₁₀C(=NR₁₉)NR₁₃R₁₄,

(CR₁₀R₂₀)_nOC(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄,

(CR₁₀R₂₀)_nNR₁₀C(Z)OR₁₀, 5-(R₁₈)-1,2,4-oxadiazol-3-yl or 4-(R₁₂)-5-(R₁₈R₁₉)-4,5-dihydro-1,2,4-oxadiazol-3-yl; wherein the aryl, arylalkyl, cycloalkyl, cycloalkylalkyl,

heteroaryl, heteroaryl alkyl, heterocyclyl and heterocyclyl alkyl groups may be optionally substituted;

Z is oxygen or sulfur;

R_a is a C₁₋₆ alkyl, aryl, arylC₁₋₆ alkyl, heterocyclyl, heterocyclylC₁₋₆ alkyl, heteroaryl, or
5 heteroarylC₁₋₆ alkyl moiety, and wherein each of these moieties may be optionally substituted;

R_b is hydrogen, C₁₋₆ alkyl, C₃₋₇ cycloalkyl, aryl, arylC₁₋₄ alkyl, heteroaryl, heteroarylC₁₋₄ alkyl, heterocyclyl, or heterocyclylC₁₋₄ alkyl;

R₃ is heterocyclyl, heterocyclylC₁₋₁₀ alkyl or R₈;

10 R₅ is hydrogen, C₁₋₄ alkyl, C₂₋₄ alkenyl, C₂₋₄ alkynyl or NR₇R₁₇, excluding the moieties SR₅ being SNR₇R₁₇ and SOR₅ being SOH;

R₆ is hydrogen, a pharmaceutically acceptable cation, C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, aryl, arylC₁₋₄ alkyl, heteroaryl, heteroarylC₁₋₄ alkyl, heterocyclyl, aroyl, or C₁₋₁₀ alkanoyl;

15 R₇ and R₁₇ is each independently selected from hydrogen or C₁₋₄ alkyl or R₇ and R₁₇ together with the nitrogen to which they are attached form a heterocyclic ring of 5 to 7 members which ring optionally contains an additional heteroatom selected from oxygen, sulfur or NR₁₅;

20 R₈ is a C₁₋₁₀ alkyl, halo-substituted C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₂₋₁₀ alkynyl, C₃₋₇ cycloalkyl, C₅₋₇ cycloalkenyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl, heteroarylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nOR₁₁, (CR₁₀R₂₀)_nS(O)_mR₁₈, (CR₁₀R₂₀)_nNHS(O)₂R₁₈, or (CR₁₀R₂₀)_nNR₁₃R₁₄ moiety; wherein the aryl, arylalkyl, heteroaryl, heteroaryl alkyl moieties may be optionally substituted;

25 R₉ is hydrogen, C(Z)R₁₁ or optionally substituted C₁₋₁₀ alkyl, S(O)₂R₁₈, optionally substituted aryl or optionally substituted arylC₁₋₄ alkyl;

R₁₀ and R₂₀ is each independently selected from hydrogen and C₁₋₄ alkyl;

R₁₁ is hydrogen, C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl or heteroarylC₁₋₁₀ alkyl;

R₁₂ is hydrogen or R₁₆;

30 R₁₃ and R₁₄ is each independently selected from hydrogen, optionally substituted C₁₋₄ alkyl, optionally substituted aryl and optionally substituted arylC₁₋₄ alkyl; or together with the nitrogen to which they are attached R₁₃ and R₁₄ form a heterocyclic ring of 5 to 7 members which ring optionally contains an additional heteroatom selected from oxygen, sulfur or NR₉;

35 R₁₅ is R₁₀ or C(Z)-C₁₋₄ alkyl;

R₁₆ is C₁₋₄ alkyl, halo-substituted-C₁₋₄ alkyl, or C₃₋₇ cycloalkyl;

R₁₈ is C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, heterocyclyl, aryl, arylC₁₋₁₀ alkyl, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, heteroaryl or heteroarylC₁₋₁₀ alkyl;

R₁₉ is hydrogen, cyano, C₁₋₄ alkyl, C₃₋₇ cycloalkyl or aryl;
or a pharmaceutically acceptable salt thereof.

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Suitably, R₁ is a substituted 4-pyridyl or 4-pyrimindyl. More suitably R₁ is substituted by an optionally substituted alkoxy, alkylthio, amino, methylamino, NHR_a, or Y. A preferred ring placement of the R₁ substituent on the 4-pyridyl derivative is the 2-position, such as in 2-methoxy-4-pyridyl. A preferred ring placement on the 4-pyrimidinyl ring is also at the 2-position, such as in 2-methoxy-pyrimidinyl.

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Suitably, R_a is a C₁₋₆ alkyl, aryl, arylC₁₋₆ alkyl, heterocyclyl, heterocyclylC₁₋₆ alkyl, heteroaryl, or heteroarylC₁₋₆ alkyl moiety, wherein each of these moieties may be optionally substituted.

When the substituent is Y, and R_a is aryl, it is preferably an optionally substituted phenyl or naphthyl. When R_a is an arylalkyl, it is preferably an optionally substituted benzyl or naphthylmethyl. When R_a is a heterocyclyl or heterocyclyl alkyl moiety, the heterocyclic portion is preferably an optionally substituted ring which is pyrrolindinyl, piperidine, morpholino, tetrahydropyran, tetrahydrothiopyran, tetrahydrothiopyran-sulfinyl, tetrahydrothio-pyransulfonyl, pyrrolindinyl, indole, or piperonyl. It is noted that the heterocyclic rings herein may contain unsaturation, such as in a tryptamine ring.

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The R_a moieties, in particular the aryl, may be optionally substituted, preferably 1 to 3 times, independently with halogen; C₁₋₄ alkyl, such as methyl, ethyl, propyl, isopropyl, or t-butyl; halosubstituted alkyl, such as CF₃; hydroxy; hydroxy substituted C₁₋₄ alkyl; C₁₋₄ alkoxy, such as methoxy or ethoxy; S(O)_malkyl and S(O)_m aryl (wherein m is 0, 1, or 2); C(O)OR₁₁, such as C(O)C₁₋₄ alkyl or C(O)OH moieties; C(O)R₁₁; OC(O)R_c; -O-(CH₂)_s-O-, such as in a ketal or dioxyalkylene bridge; amino; mono- and di-C₁₋₆ alkylsubstituted amino; N(R₁₀)C(O)R_b; C(O)NR₁₀R₂₀; cyano; nitro; or an N-heterocyclyl ring which ring has from 5 to 7 members and optionally contains an additional heteroatom selected from oxygen, sulfur or NR₁₅; optionally substituted aryl, such as phenyl; optionally substituted arylalkyl, such as benzyl or phenethyl; optionally substituted aryloxy, such as phenoxy; or optionally substituted arylalkyloxy such as benzyloxy. The aryl, arylalkyl, aryloxy, or arylalkyloxy optional substituents are as defined in the "optional substituent" definition herein.

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Suitably, R_c is an optionally substituted C₁₋₆ alkyl, optionally substituted C₃₋₇ cycloalkyl, optionally substituted aryl, optionally substituted arylC₁₋₄ alkyl, optionally substituted heteroaryl, optionally substituted heteroarylC₁₋₄ alkyl, optionally substituted

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heterocyclyl, or optionally substituted heterocyclylC₁₋₄ alkyl moieties; and wherein the optional substituents are as defined in the "optional substituent" definition herein.

Preferably, the R_a groups include C₁₋₄ alkyl, benzyl, halosubstituted benzyl, naphthylmethyl, phenyl, halosubstituted phenyl, aminocarbonylphenyl, alkylphenyl, 5 cyanophenyl, alkylthiophenyl, hydroxyphenyl, alkoxyphenyl, morpholinopropyl, piperonyl, piperidin-4-yl, alkyl substituted piperidine, such as 1-methylpiperidine, or 2,2,6,6-tetramethylpiperidin-4-yl.

Preferably, when the substituent is NHR_a then R_a is aryl, arylalkyl, halosubstituted arylalkyl, halosubstituted aryl, heterocyclyl alkyl, hydroxy alkyl, alkyl-1-piperidine-10 carboxylate, heterocyclyl, alkyl substituted heterocyclyl, halosubstituted heterocyclyl, or aryl substituted heterocyclyl. More preferably, R_a is benzyl, halosubstituted benzyl, naphthylmethyl, phenyl, halosubstituted phenyl, morpholinopropyl, 2-hydroxy ethyl, ethyl-1-piperidinecarboxylate, piperonyl, piperidin-4-yl, alkyl substituted piperidine, chlorotryptamine, or tetrathiohydropyranlyl.

15 Preferably, when the R₁ substituent is an optionally substituted C₁₋₄ alkoxy or C₁₋₄ alkylthio, it is preferably a methoxy group. If the alkyl chain in these moieties is optionally substituted it is preferably substituted by halogen, such as fluorine, chlorine, bromine or iodine; hydroxy, such as hydroxyethoxy; C₁₋₁₀ alkoxy, such as a methoxymethoxy, S(O)_m alkyl, wherein m is 0, 1 or 2; amino, mono and di-substituted 20 amino, such as in the NR₇R₁₇ group, i.e. tert-butylaminoethoxy; or where the R₇R₁₇ may together with the nitrogen to which they are attached cyclize to form a 5 to 7 membered ring which optionally includes an additional heteroatom selected from O/N/S; C₁₋₁₀ alkyl, cycloalkyl, or cycloalkyl alkyl group, such as methyl, ethyl, propyl, isopropyl, t-butyl, etc. or cyclopropyl methyl; or halosubstituted C₁₋₁₀ alkyl, such as CF₃.

25 Suitably, R₄ is an optionally substituted phenyl. Preferably the phenyl is substituted one or more times independently by halogen, SR₅, S(O)R₅, OR₁₂, halo-substituted-C₁₋₄ alkyl, or C₁₋₄ alkyl, preferably in the 4-position of the ring. More preferably R₄ is a halosubstituted phenyl, more preferably in the 4-position; and most preferably by fluorine.

30 Suitably, R₂ is hydrogen, (CR₁₀R₂₀)_n OR₉, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, C₁₋₁₀ alkyl, halo-substituted C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₂₋₁₀ alkynyl, C₃₋₇ cycloalkyl, C₃₋₇ cycloalkylC₁₋₁₀ alkyl, C₅₋₇ cycloalkenyl, C₅₋₇ cycloalkenylC₁₋₁₀ alkyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl, heteroarylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nOR₁₁, (CR₁₀R₂₀)_nS(O)_mR₁₈, (CR₁₀R₂₀)_nNHS(O)₂R₁₈, (CR₁₀R₂₀)_nNR₁₃R₁₄, 35 (CR₁₀R₂₀)_nNO₂, (CR₁₀R₂₀)_nCN, (CR₁₀R₂₀)_nSO₂R₁₈, (CR₁₀R₂₀)_nS(O)_mNR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)R₁₁, (CR₁₀R₂₀)_nOC(Z)R₁₁, (CR₁₀R₂₀)_nC(Z)OR₁₁, (CR₁₀R₂₀)_nC(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)NR₁₁OR₉, (CR₁₀R₂₀)_nNR₁₀C(Z)R₁₁,

(CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nN(OR₆)C(Z)NR₁₃R₁₄,
 (CR₁₀R₂₀)_nN(OR₆)C(Z)R₁₁, (CR₁₀R₂₀)_nC(=NOR₆)R₁₁,
 (CR₁₀R₂₀)_nNR₁₀C(=NR₁₉)NR₁₃R₁₄, (CR₁₀R₂₀)_nOC(Z)NR₁₃R₁₄,
 (CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nNR₁₀C(Z)OR₁₀, 5-(R₁₈)-1,2,4-oxadiazol-
 5 3-yl or 4-(R₁₂)-5-(R₁₈R₁₉)-4,5-dihydro-1,2,4-oxadiazol-3-yl group, and wherein the aryl,
 arylalkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, heteroaryl alkyl, heterocyclyl and
 heterocyclyl alkyl groups may be optionally substituted.

Suitably, R₂ is hydrogen, optionally substituted heterocyclyl, optionally
 substituted heterocyclylC₁₋₁₀ alkyl, optionally substituted C₁₋₁₀ alkyl, optionally
 10 substituted C₃₋₇ cycloalkyl, optionally substituted C₃₋₇ cycloalkylC₁₋₁₀ alkyl,
 (CR₁₀R₂₀)_nC(Z)OR₁₁, (CR₁₀R₂₀)_nNR₁₃R₁₄, (CR₁₀R₂₀)_nNHS(O)₂R₁₈,
 (CR₁₀R₂₀)_nS(O)_mR₁₈, optionally substituted aryl, optionally substituted arylC₁₋₁₀
 alkyl, (CR₁₀R₂₀)_nOR₁₁, (CR₁₀R₂₀)_nC(Z)R₁₁, or (CR₁₀R₂₀)_nC(=NOR₆)R₁₁.

More suitably, R₂ is selected from hydrogen, optionally substituted C₁₋₁₀ alkyl,
 15 optionally substituted heterocyclyl, optionally substituted heterocyclylC₁₋₁₀ alkyl,
 (CR₁₀R₂₀)_nNS(O)₂R₁₈, (CR₁₀R₂₀)_nS(O)_mR₁₈, arylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nNR₁₃R₁₄,
 optionally substituted C₃₋₇ cycloalkyl, or optionally substituted C₃₋₇ cycloalkylC₁₋₁₀
 alkyl.

Preferably R₂ is hydrogen, morpholino propyl, piperidine, N-methylpiperidine,
 20 N-benzylpiperidine, 2,2,6,6-tetramethylpiperidine, 4-aminopiperidine, 4-amino-2,2,6,6-
 tetramethylpiperidine, 4-hydroxycyclohexyl, 4-methyl-4-hydroxycyclohexyl,
 4-pyrrolinindylcyclohexyl, 4-methyl-4-aminocyclohexyl, 4-methyl-4-acetamidocyclohexyl,
 4-ketocyclohexyl, 4-oxiranyl, or 4-hydroxy-4-(1-propynyl)cyclohexyl.

More preferably R₂ is an optionally substituted heterocyclyl ring, optionally
 25 substituted heterocyclylC₁₋₁₀ alkyl, optionally substituted aryl, (CR₁₀R₂₀)_nNR₁₃R₁₄, or
 (CR₁₀R₂₀)_nC(Z)OR₁₁ group. Most preferably an optionally substituted heterocyclyl ring,
 or optionally substituted heterocyclylC₁₋₁₀ alkyl.

When R₂ is optionally substituted heterocyclyl, the ring is preferably a morpholino,
 pyrrolidinyl, or a piperidinyl group. When the ring is optionally substituted, the
 30 substituents may be directly attached to the free nitrogen, such as in the piperidinyl group
 or pyrrole ring, or on the ring itself. Preferably the ring is a piperidine or pyrrole, more
 preferably piperidine. The heterocyclyl ring may be optionally substituted one to four
 times independently by halogen; C₁₋₄ alkyl; aryl, such as phenyl; aryl alkyl, such as benzyl
 - wherein the aryl or aryl alkyl moieties themselves may be optionally substituted (as in the
 35 "optionally substituted" definition below); C(O)OR₁₁, such as the C(O)C₁₋₄ alkyl or
 C(O)OH moieties; C(O)H; C(O)C₁₋₄ alkyl; hydroxy substituted C₁₋₄ alkyl; C₁₋₄ alkoxy;

$S(O)_mC_{1-4}$ alkyl (wherein m is 0, 1, or 2); and $NR_{10}R_{20}$ (wherein R_{10} and R_{20} are independently hydrogen or C_{1-4} alkyl).

Preferably if the ring is a piperidine, the ring is attached to the imidazole at the 4-position, and the substituents are directly on the available nitrogen, i.e. a

5 1-formyl-4-piperidine, 1-benzyl-4-piperidine, 1-methyl-4-piperidine, or 1-ethoxycarbonyl-4-piperidine. If the ring is substituted by an alkyl group and the ring is attached in the 4-position, it is preferably substituted in the 2- or 6- position or both, such as 2,2,6,6-tetramethyl-4-piperidine. Similarly, if the ring is a pyrrole, the ring is attached to the imidazole at the 3-position, and the substituents are all directly on the available nitrogen.

10 When R_2 is an optionally substituted heterocyclyl C_{1-10} alkyl group, the ring is preferably a morpholino, pyrrolidinyl, or a piperidinyl group. Preferably the alkyl linking moiety is from 1 to 4, more preferably 3 or 4, and most preferably 3 carbons, such as in a propyl group. Preferred heterocyclyl alkyl groups include but are not limited to, morpholino ethyl, morpholino propyl, pyrrolidinyl propyl, and piperidinyl propyl moieties.

15 The heterocyclic ring herein is also optionally substituted in a similar manner to that indicated above for the direct attachment of the heterocyclyl ring.

When R_2 is an optionally substituted C_{3-7} cycloalkyl, or an optionally substituted C_{3-7} cycloalkyl C_{1-10} alkyl, the cycloalkyl group is preferably a C_4 or C_6 ring, most preferably a C_6 ring, which ring is optionally substituted.

20 The cycloalkyl ring may be optionally substituted one to three times independently by halogen, such as fluorine, chlorine, bromine or iodine; hydroxy; C_{1-10} alkoxy, such as methoxy or ethoxy; $S(O)_m$ alkyl, wherein m is 0, 1, or 2, such as methyl thio, methylsulfinyl or methyl sulfonyl; $S(O)_m$ aryl; cyano; nitro; amino; mono and di- C_{1-10} alkyl substituted amino, such as in the NR_7R_{17} group, wherein

25 R_7 and R_{17} are as defined in Formula (I), or where the R_7R_{17} may cyclize together with the nitrogen to which they are attached to form a 5 to 7 membered ring which optionally includes an additional heteroatom selected from oxygen, sulfur or NR_{15} ; $N(R_{10})C(O)X_1$, wherein X_1 is C_{1-4} alkyl, aryl or aryl C_{1-4} alkyl; C_{1-10} alkyl, such as methyl, ethyl, propyl, isopropyl, or t-butyl; optionally substituted alkyl wherein the

30 substituents are halogen, (such as CF_3), hydroxy, nitro, cyano, amino, mono & di- C_{1-10} alkyl substituted amino; NR_7R_{17} ; $S(O)_m$ alkyl and $S(O)_m$ aryl, wherein m is 0, 1 or 2; optionally substituted alkylene, such as ethylene or propylene; optionally substituted alkyne, such as ethyne; $C(O)OR_{11}$; the group R_e ; $C(O)H$; $=O$; $=N-OR_{11}$; $N(H)-OH$ (or substituted alkyl or aryl derivatives thereof on the nitrogen or the oxime moiety); $N(OR_d)-C(O)-R_6$; an optionally substituted aryl, such as phenyl; an

35 optionally substituted aryl C_{1-4} alkyl, such as benzyl or phenethyl; an optionally substituted heterocyclyl or heterocyclyl C_{1-4} alkyl, and further wherein these aryl,

arylalkyl, heterocyclyl, and heterocyclyl alkyl moieties are optionally substituted one to two times by halogen, hydroxy, C₁₋₁₀ alkoxy, S(O)_m alkyl, cyano, nitro, amino, mono and di-C₁₋₁₀ alkyl substituted amino, alkyl, or halosubstituted alkyl.

Suitably R_d is hydrogen, a pharmaceutically acceptable cation, aroyl or a C₁₋₁₀ alkanoyl group.

Suitably R_e is a 1,3-dioxyalkylene group of the formula -O-(CH₂)_s-O-, wherein s is 1 to 3, preferably s is 2 yielding a 1,3-dioxyethylene moiety, or ketal functionality.

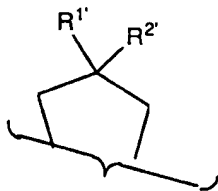
Suitably R_{6'} is NR_{19'}R_{20'}; C₁₋₆ alkyl; halosubstituted C₁₋₆ alkyl; hydroxy substituted C₁₋₆ alkyl; C₂₋₆ alkenyl; or an aryl or heteroaryl optionally substituted by halogen, C₁₋₆ alkyl, halosubstituted C₁₋₆ alkyl, hydroxyl, or C₁₋₆ alkoxy.

Suitably R_{19'} is H or C₁₋₆ alkyl.

Suitably R_{20'} is H, C₁₋₆ alkyl, aryl, benzyl, heteroaryl, C₁₋₆ alkyl substituted by halogen or hydroxyl, or phenyl substituted by a member selected from the group consisting of halo, cyano, C₁₋₁₂ alkyl, C₁₋₆ alkoxy, halosubstituted C₁₋₆ alkyl, C₁₋₆ alkylthio, C₁₋₆ alkylsulphonyl, or C₁₋₆ alkylsulfinyl; or R_{19'} and R_{20'} may together with the nitrogen to which they are attached form a ring having 5 to 7 members, which members of the ring may be optionally replaced by a heteroatom selected from oxygen, sulfur or nitrogen. The ring may be saturated or contain more than one unsaturated bond. Preferably R_{6'} is NR_{19'}R_{20'} and R_{19'} and R_{20'} are preferably hydrogen.

When the R₂ cycloalkyl moiety is substituted by a NR₇R₁₇ group, or NR₇R₁₇ C₁₋₁₀ alkyl group, and the R₇ and R₁₇ are as defined in Formula (I), the substituent is preferably an amino, amino alkyl, or an optionally substituted pyrrolidinyl moiety.

A preferred ring placement on the cycloalkyl moiety is the 4-position, such as in a C₆ ring. When the cycloalkyl ring is di-substituted it is preferably di-substituted at the 4 position, such as in:



wherein R^{1'} and R^{2'} are independently the optional substituents indicated above for R₂. Preferably, R^{1'} and R^{2'} are hydrogen, hydroxy, alkyl, substituted alkyl, optionally substituted alkyne, aryl, arylalkyl, NR₇R₁₇, and N(R₁₀)C(O)R₁₁. Suitably, the alkyl is a C₁₋₄ alkyl, such as methyl, ethyl, or isopropyl; NR₇R₁₇ and NR₇R₁₇ alkyl, such as amino, methylamino, aminomethyl, aminoethyl; substituted alkyl such as in cyanomethyl, cyanoethyl, nitroethyl, pyrrolidinyl; aryl such as in phenyl; arylalkyl, such as in benzyl;

optionally substituted alkyne, such as ethyne or propynyl; or together R¹' and R²' are a keto functionality.

Preferably R₄ is an optionally substituted phenyl; R₁ is an optionally substituted 4-pyridyl or 4-pyrimidinyl; and R₂ is an optionally substituted heterocyclyl, heterocyclyl C₁₋₄ alkyl, a cycloalkyl or a cycloalkyl alkyl. More preferably R₂ is an optionally substituted C₄ or C₆ cycloalkyl, cyclopropyl methyl, morpholinyl butyl, morpholinyl propyl, morpholinyl ethyl, cyclohexyl substituted by methyl, phenyl, benzyl, amino, acetamide, aminomethyl, aminoethyl, cyanomethyl, cyanoethyl, hydroxy, nitroethyl, pyrrolidinyl, ethynyl, 1-propynyl, =O, -O-(CH₂)₂O-, =NOR₁₁, wherein R₁₁ is hydrogen, alkyl or aryl, NHOH, or N(OH)-C(O)-NH₂; or R₂ is morpholinyl propyl, aminopropyl, piperidinyl, N-benzyl-4-piperidinyl, N-methyl-4-piperidinyl, 2,2,6,6-tetramethylpiperidinyl, substituted piperidine, such as 1-formyl-4-piperidine, or a 1-ethoxycarbonyl-4-piperidine. More preferably R₁ is a 4-pyridyl or 4-pyrimidinyl substituted by Y, NHR_a, or C₁₋₄ alkoxy.

In all instances herein where there is an alkenyl or alkynyl moiety as a substituent group, the unsaturated linkage, i.e., the vinylene or acetylene linkage is preferably not directly attached to the nitrogen, oxygen or sulfur moieties, for instance in OR₃, or for certain R₂ moieties.

As used herein, "optionally substituted", unless specifically defined, shall mean such groups as halogen, such as fluorine, chlorine, bromine or iodine; hydroxy; hydroxy substituted C₁₋₁₀ alkyl; C₁₋₁₀ alkoxy, such as methoxy or ethoxy; S(O)_m alkyl, wherein m is 0, 1 or 2, such as methylthio, methylsulfinyl or methylsulfonyl; amino, mono and di-C₁₋₁₀ alkyl substituted amino, NR₇R₁₇ wherein the R₇R₁₇ may together with the nitrogen to which they are attached cyclize to form a 5 to 7 membered ring which optionally includes an additional heteroatom selected from O/N/S; C₁₋₁₀ alkyl, cycloalkyl, or cycloalkyl alkyl group, such as methyl, ethyl, propyl, isopropyl, t-butyl, etc. or cyclopropyl methyl; halosubstituted C₁₋₁₀ alkyl, such as CF₃; an optionally substituted aryl, such as phenyl, or an optionally substituted arylalkyl, such as benzyl or phenethyl, wherein these aryl moieties may also be substituted one to two times by halogen; hydroxy; hydroxy substituted alkyl; C₁₋₁₀ alkoxy; S(O)_m alkyl; amino, mono and di-C₁₋₁₀ alkyl substituted amino, such as in the NR₇R₁₇ group; C₁₋₁₀ alkyl; or halosubstituted alkyl, such as CF₃.

Suitable pharmaceutically acceptable salts are well known to those skilled in the art and include basic salts of inorganic and organic acids, such as hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, methane sulphonic acid, ethane sulphonic acid, acetic acid, malic acid, tartaric acid, citric acid, lactic acid, oxalic acid, succinic acid, fumaric acid, maleic acid, benzoic acid, salicylic acid, phenylacetic acid and mandelic acid. In addition, pharmaceutically acceptable salts of compounds of Formula (I) may also be

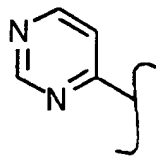
formed with a pharmaceutically acceptable cation, for instance, if a substituent group comprises a carboxy moiety. Suitable pharmaceutically acceptable cations are well known to those skilled in the art and include alkaline, alkaline earth, ammonium and quaternary ammonium cations.

5 The following terms, as used herein, refer to:

- "halo" or "halogens", include the halogens: chloro, fluoro, bromo and iodo.
- "C₁₋₁₀alkyl" or "alkyl" - both straight and branched chain radicals of 1 to 10 carbon atoms, unless the chain length is otherwise limited, including, but not limited to, methyl, ethyl, *n*-propyl, *iso*-propyl, *n*-butyl, *sec*-butyl, *iso*-butyl, *tert*-butyl, *n*-pentyl and the like.
- 10 • The term "cycloalkyl" is used herein to mean cyclic radicals, preferably of 3 to 8 carbons, including but not limited to cyclopropyl, cyclopentyl, cyclohexyl, and the like.
- The term "cycloalkenyl" is used herein to mean cyclic radicals, preferably of 5 to 8 carbons, which have at least one double bond including but not limited to cyclopentenyl, cyclohexenyl, and the like.
- 15 • The term "alkenyl" is used herein at all occurrences to mean straight or branched chain radical of 2-10 carbon atoms, unless the chain length is limited thereto, including, but not limited to ethenyl, 1-propenyl, 2-propenyl, 2-methyl-1-propenyl, 1-butenyl, 2-butenyl and the like.
- 20 • "aryl" - phenyl and naphthyl;
- "heteroaryl" (on its own or in any combination, such as "heteroaryloxy", or "heteroarylalkyl") - a 5-10 membered aromatic ring system in which one or more rings contain one or more heteroatoms selected from the group consisting of N, O or S, such as, but not limited, to pyrrole, pyrazole, furan, thiophene, quinoline, isoquinoline,
- 25 quinazolinyl, pyridine, pyrimidine, oxazole, thiazole, thiadiazole, triazole, imidazole, or benzimidazole.
- "heterocyclyl" (on its own or in any combination, such as "heterocyclylalkyl") - a saturated or partially unsaturated 4-10 membered ring system in which one or more rings contain one or more heteroatoms selected from the group consisting of N, O, or S; such as,
- 30 but not limited to, pyrrolidine, piperidine, piperazine, morpholine, tetrahydropyran, or imidazolidine.
- The term "aralkyl" or "heteroarylalkyl" or "heterocyclylalkyl" is used herein to mean C₁₋₄ alkyl as defined above attached to an aryl, heteroaryl or heterocyclyl moiety as also defined herein unless otherwise indicated.
- 35 • "sulfinyl" - the oxide S(O) of the corresponding sulfide, the term "thio" refers to the sulfide, and the term "sulfonyl" refers to the fully oxidized S(O)₂ moiety.

- "aroyl" - a C(O)Ar, wherein Ar is a phenyl, naphthyl, or aryl alkyl derivative such as defined above, such groups include but are not limited to benzyl and phenethyl.
- "alkanoyl" - a C(O)C₁₋₁₀ alkyl wherein the alkyl is as defined above.

For the purposes herein the "core" 4-pyrimidinyl moiety for R₁ or R₂ is referred to
5 as the formula:



It is recognized that the compounds for use in the present invention may exist as stereoisomers, regioisomers, or diastereoisomers. These compounds may contain one or more asymmetric carbon atoms and may exist in racemic and optically active
10 forms. All of these compounds are included within the scope of the present invention.

As noted previously, methods of making these compounds can be found in their respective patent applications as noted above.

- 15 Specifically exemplified compounds of Formula (I) include:
- 1-[3-(4-Morpholinyl)propyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-(3-Chloropropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-(3-Azidopropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-(3-Aminopropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 20 1-(3-Methylsulfonamidopropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(N-Phenylmethyl)aminopropyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(N-Phenylmethyl-N-methyl)aminopropyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(1-Pyrrolidinyl)propyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 25 1-(3-Diethylaminopropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(1-Piperidinyl)propyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(Methylthio)propyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[2-(4-Morpholinyl)ethyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(4-Morpholinyl)propyl]-4-(3-methylthiophenyl)-5-(4-pyridyl)imidazole;
 - 30 (+/-)-1-[3-(4-Morpholinyl)propyl]-4-(3-methylsulfinylphenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(N-Methyl-N-benzyl)aminopropyl]-4-(3-methylthiophenyl)-5-(4-pyridyl)imidazole;
 - 1-[3-(N-Methyl-N-benzyl)aminopropyl]-4-(3-methylsulfinylphenyl)-5-(4-pyridyl)imidazole;

- 1-[4-(Methylthio)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-[4-(Methylsulfinyl)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-[3-(Methylthio)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 (+/-)-1-[3-(Methylsulfinyl)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 5 1-[2-(Methylthio)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-[2-(Methylsulfinyl)phenyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-[4-(4-Morpholinyl)butyl]-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-Cyclopropyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-Isopropyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 10 1-Cyclopropylmethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-tert-Butyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-(2,2-Diethoxyethyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-Formylmethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-Hydroxyiminylmethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 15 1-Cyanomethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-[3-(4-Morpholinyl)propyl]-4-(4-fluorophenyl)-5-(2-methylpyridin-4-yl)imidazole;
 4-(4-Fluorophenyl)-1-[3-(4-morpholinyl)propyl]-5-(2-chloropyridin-4-yl)imidazole;
 4-(4-Fluorophenyl)-1-[3-(4-morpholinyl)propyl]-5-(2-amino-4-pyridyl)imidazole;
 1-(4-Carboxymethyl)propyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 20 1-(4-Carboxypropyl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-(3-Carboxymethyl)ethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-(3-Carboxy)ethyl-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 1-(1-Benzylpiperidin-4-yl)-4-(4-fluorophenyl)-5-(4-pyridyl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-[3-(4-morpholinyl)propyl]imidazole;
 25 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(1-benzylpiperidin-4-yl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(2-propyl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(cyclopropylmethyl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(1-carboxyethyl-4-piperidinyl)imidazole;
 30 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
 1-Methyl-4-phenyl-5-(4-pyridyl)imidazole;
 1-Methyl-4-(3-chlorophenyl)-5-(4-pyridinyl)imidazole;
 1-Methyl-4-(3-methylthiophenyl)-5-(4-pyridyl)imidazole;
 (+/-)-1-Methyl-4-(3-methylsulfinylphenyl)-5-(4-pyridyl)imidazole;
 35 (+/-)-4-(4-Fluorophenyl)-1-[3-(methylsulfinyl)propyl]-5-(4-pyridinyl)imidazole;
 4-(4-Fluorophenyl)-1-[3-(methylsulfonyl)propyl]-5-(4-pyridinyl)imidazole;
 1-(3-Phenoxypropyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;

- 1-[3-(Phenylthio)propyl]-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 1-[3-(4-Morpholinyl)propyl]-4-(4-fluorophenyl)-5-(4-quinolyl)imidazole;
 (+/-)-1-(3-Phenylsulfinylpropyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 1-(3-Ethoxypropyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 5 1-(3-Phenylsulfonylpropyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 1-[3-(4-Morpholinyl)propyl]-4-(3-chlorophenyl)-5-(4-pyridyl)imidazole;
 1-[3-(4-Morpholinyl)propyl]-4-(3,4-dichlorophenyl)-5-(4-pyridyl)imidazole;
 4-[4-(4-Fluorophenyl)-1-[3-(4-morpholinyl)propyl]-5-(pyrimid-2-one-4-yl)imidazole;
 4-(4-Fluorophenyl)-5-[2-(methylthio)-4-pyrimidinyl]-1-[3-(4-morpholinyl)propyl]-
 10 imidazole;
 (+/-)-4-(4-Fluorophenyl)-5-[2-(methylsulfinyl)-4-pyrimidinyl]-1-[3-(4-morpholinyl)-
 propyl]imidazole;
 (E)-1-(1-Propenyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 1-(2-Propenyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 15 5-[(2-N,N-Dimethylamino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-[3-(4-morpholinyl)-
 propyl]imidazole;
 1-[3-(4-Morpholinyl)propyl]-5-(4-pyridinyl)-4-[4-(trifluoromethyl)phenyl]imidazole;
 1-[3-(4-Morpholinyl)propyl]-5-(4-pyridinyl)-4-[3-(trifluoromethyl)phenyl]imidazole;
 1-(Cyclopropylmethyl)-4-(3,4-dichlorophenyl)-5-(4-pyridinyl)imidazole;
 20 1-(Cyclopropylmethyl)-4-(3-trifluoromethylphenyl)-5-(4-pyridinyl)imidazole;
 1-(Cyclopropylmethyl)-4-(4-fluorophenyl)-5-(2-methylpyrid-4-yl)imidazole;
 1-[3-(4-Morpholinyl)propyl]-5-(4-pyridinyl)-4-(3,5-bistrifluoromethylphenyl)-
 imidazole;
 5-[4-(2-Aminopyrimidinyl)]-4-(4-fluorophenyl)-1-(2-carboxy-2,2-
 25 dimethylethyl)imidazole;
 1-(1-Formyl-4-piperidinyl)-4-(4-fluorophenyl)-5-(4-pyridinyl)imidazole;
 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(1-methyl-4-piperidinyl)imidazole;
 1-(2,2-Dimethyl-3-morpholin-4-yl)propyl-4-(4-fluorophenyl)-5-(2-amino-4-
 pyrimidinyl)imidazole;
 30 4-(4-Fluorophenyl)-5-(4-pyridyl)-1-(2-acetoxyethyl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(1-benzylpyrrolin-3-yl)imidazole;
 5-(2-Aminopyrimidin-4-yl)-4-(4-fluorophenyl)-1-(2,2,6,6-tetramethylpiperidin-4-
 yl)imidazole;
 5-[4-(2-N-Methylamino)pyrimidinyl]-4-(4-fluorophenyl)-1-(4-N-methylpiperidine)-
 35 imidazole;
 5-[4-(2-N-Methylamino)pyrimidinyl]-4-(4-fluorophenyl)-1-(4-N-morpholino-1-
 propyl)imidazole;

- 5-[4-(2-N-Methylamino)pyrimidinyl]-4-(4-fluorophenyl)-1-(4-piperidine)imidazole;
 5-[(2-Ethylamino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
 4-(4-Fluorophenyl)-5-[2-(isopropyl)aminopyrimidin-4-yl]-1-(1-methylpiperidin-4-yl)imidazole;
- 5 5-(2-Acetamido-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(4-N-morpholino-1-propyl)-imidazole;
 5-(2-Acetamido-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(1-methyl-4-piperidinyl)imidazole;
 5-[4-(2-N-Methylthio)pyrimidinyl]-4-(4-fluorophenyl)-1-(4-piperidine)imidazole;
 4-(Fluorophenyl)-1-(methyl-4-piperidinyl)-5-(2-methylthio-4-pyrimidinyl)imidazole;
- 10 4-(Fluorophenyl)-1-(methyl-4-piperidinyl)-5-(2-methylsulfinyl-4-pyrimidinyl)imidazole;
 1-tert-Butyl-4-(4-fluorophenyl)-5-(2-methylsulfinyl-4-pyrimidinyl)imidazole;
 5-[4-(2-Aminopyrimidinyl)]-4-(4-fluorophenyl)-1-(2,2,6,6-tetramethyl-4-piperidinyl)imidazole;
- 15 5-[4-(2-N-Methylamino-4-pyrimidinyl)]-4-(4-fluorophenyl)-1-(2,2,6,6-tetramethyl-4-piperidine)imidazole;
 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(tetrahydro-4-thiopyranyl)imidazole;
 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(tetrahydro-4-pyranyl)imidazole;
 5-(2-Methylamino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(2-cyanoethyl)imidazole;
 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(tetrahydro-4-sulfinylpyranyl)imidazole;
- 20 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(tetrahydro-4-sulfonylpyranyl)-imidazole;
 5-(2-Methylamino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(2,2,2-trifluoroethyl-4-piperidinyl)imidazole;
 5-(2-Amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(trifluoroacetyl-4-piperidinyl)-imidazole;
- 25 5-(4-Pyridyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
 5-(4-Pyridyl)-4-(4-fluorophenyl)-1-(1-t-butoxy carbonyl-4-piperidinyl)imidazole;
 4-(4-Fluorophenyl)-5-(4-pyridyl)imidazole;
 4-(4-Fluorophenyl)-5-(2-methoxy-pyrimidin-4-yl)imidazole;
- 30 4-(4-Fluorophenyl)-5-(2-methylthio-pyrimidin-4-yl)imidazole;
 5-[(2-Benzylamino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
 4-(4-Fluorophenyl)-1-(1-methylpiperidin-4-yl)-5-[2-(4-tetrahydrothio-pyranyl)aminopyrimidin-4-yl]imidazole;
- 35 5-[(2-(3-Chlorobenzylamino))pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methyl-piperidin-4-yl)imidazole;

- 5-[(2-(1-Naphthylmethylamino))pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5-[(2-(1-Benzyl-4-piperidinylamino))pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5 4-(4-Fluorophenyl)-1-(1-methylpiperidin-4-yl)-5-[2-[3-(morpholino)propyl]-aminopyrimidin-4-yl]imidazole;
- 5-[2-[(3-Bromophenyl)amino]pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5-[(2-(Piperonylamino)pyrimidin-4-yl)-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 10 5-[(2-(4-Piperidinylamino))pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5-[(2-(5-Chlorotryptamino))pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 15 5-[(2-(2,2,6,6-Tetramethylpiperidin-4-yl)amino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5-[(2-(1-Ethoxycarbonyl)piperidin-4-yl)aminopyrimidin-4-yl]-4-(4-fluorophenyl)-1-(1-methylpiperidin-4-yl)imidazole;
- 5-[2-(Phenylamino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(4-oxocyclohexyl)imidazole;
- 20 5-[4-(2-Phenylamino)pyrimidin-4-yl]-4-(4-fluorophenyl)-1-(4-hydroxycyclohexyl)-imidazole;
- 4-(4-Fluorophenyl)-1-(1-methylpiperidin-4-yl)-5-[(2-phenylamino)pyrimidin-4-yl]-imidazole;
- 4-(4-Fluorophenyl)-1-(2,2,6,6-tetramethylpiperidin-4-yl)-5-[(2-phenylamino)pyrimidin-4-yl]imidazole;
- 25 4-(4-Fluorophenyl)-5-[(2-phenylamino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[2-[3-(imidazol-1-yl)propyl]aminopyrimidin-4-yl]-1-[(1-t-butoxycarbonyl)piperidin-4-yl]imidazole;
- 4-(4-Fluorophenyl)-5-[2-[3-(imidazol-1-yl)propyl]aminopyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 30 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-anilino-4-pyridinyl)imidazole;
- 4-(4-Thiomethylphenyl)-5-[(2-phenylamino)pyrimidin-4-yl]-1-(1-ethoxycarbonylpiperidin-4-yl)imidazole;
- 4-(4-Thiomethylphenyl)-5-[(2-phenylamino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 35 4-(4-Methylsulfinylphenyl)-5-[(2-phenylamino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;

- 4-(4-Fluorophenyl)-5-[(2-(4-fluorophenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(3-fluorophenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 5 4-(4-Fluorophenyl)-5-[(2-(2-fluorophenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(4-benzyloxyphenyl)amino)pyrimidin-4-yl]-1-(1-ethoxycarbonylpiperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(3-benzyloxyphenyl)amino)pyrimidin-4-yl]-1-(1-ethoxycarbonylpiperidin-4-yl)imidazole;
- 10 4-(4-Fluorophenyl)-5-[(2-(3-trifluoromethylphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(3,4-difluorophenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 15 4-(4-Fluorophenyl)-5-[(2-(4-hydroxyphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(3-hydroxyphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(4-methoxyphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 20 4-(4-Fluorophenyl)-5-[(2-(3-methoxyphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 4-(4-Fluorophenyl)-5-[(2-(2-methoxyphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 25 4-(4-Fluorophenyl)-5-[(2-(3-fluoro-2-methylphenyl)amino)pyrimidin-4-yl]-1-(piperidin-4-yl)imidazole;
- 1-(4-Oxocyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)pyrimidin-4-yl]imidazole;
- cis*-1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)pyrimidin-4-yl]imidazole;
- 30 *trans*-1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)pyrimidin-4-yl]imidazole;
- 1-(4-Oxocyclohexyl)-4-(4-fluorophenyl)-5-[(2-methylthio)pyrimidin-4-yl]imidazole;
- trans*-1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-methylthio)pyrimidin-4-yl]imidazole;
- 35 1-(4-Oxocyclohexyl)-4-(4-fluorophenyl)-5-[(2-hydroxy)pyrimidin-4-yl]imidazole;
- 1-(4-Oxocyclohexyl)-4-(4-fluorophenyl)-5-[(2-isopropoxy)pyrimidin-4-

- yl]imidazole;
 1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-isopropoxy)pyrimidin-4-yl]imidazole;
trans-1-(4-Hydroxy-4-methylcyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)-pyrimidin-4-yl]imidazole;
 5 *cis*-1-(4-Hydroxy-4-methylcyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)-pyrimidin-4-yl]imidazole;
trans-1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-ethoxy)pyrimidine-4-yl]imidazole;
 10 1-Cycloheptyl-4-(4-fluorophenyl)-5-(2-methoxypyrimidin-4-yl)imidazole;
 1-Cyclopropyl-4-(4-fluorophenyl)-5-(2-methoxypyrimidin-4-yl)imidazole;
 1-Cyclobutyl-4-(4-fluorophenyl)-5-(2-methoxypyrimidin-4-yl)imidazole;
 1-Cyclopentyl-4-(4-fluorophenyl)-5-(2-methoxypyrimidin-4-yl)imidazole;
 1-Cyclohexyl-4-(4-fluorophenyl)-5-(2-methoxypyrimidin-4-yl)imidazole;
 15 *trans*-5-[4-(2-Methoxy)pyrimidinyl]-4-(4-fluorophenyl)-1-[4-(2-tetrahydropyranyl)-oxycyclohexyl]imidazole;
 1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[(2-hydroxy)pyrimidin-4-yl]imidazole
cis-1-[(4-Hydroxy-4-methylcyclohexyl)]-4-(4-fluorophenyl)-5-(2-methoxy-4-
 20 pyrimidinyl)imidazole;
trans-1-[(4-Hydroxy-4-methylcyclohexyl)]-4-(4-fluorophenyl)-5-(2-methoxy-4-pyrimidinyl)imidazole;
trans-1-(4-Aminocyclohexyl)-4-(4-fluorophenyl)-5-(2-methoxy-4-pyrimidinyl)imidazole;
 25 *trans*-4-(4-Fluorophenyl)-5-[(2-methoxy)pyrimidin-4-yl]-1-[4-((methylthio)methoxy)cyclohexyl]imidazole;
cis-1-(4-Aminocyclohexyl)-4-(4-fluorophenyl)-5-(2-methoxy-4-pyrimidinyl)imidazole;
trans-1-[(4-Butyryloxy)cyclohexyl]-4-(4-fluorophenyl)-5-[(2-methoxypyrimidin)-4-yl]imidazole;
 30 *trans*-4-(4-Fluorophenyl)-1-[4-(2-(N,N-dimethylamino)ethoxy)cyclohexyl]-5-[(2-methoxy)pyrimidin-4-yl]imidazole hydrochloride;
cis/trans-1-(4-Hydroxy-4-hydroxymethylcyclohexyl)-4-(4-fluorophenyl)-5-[(2-methoxy)pyrimidin-4-yl]imidazole;
 35 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyridin-4-yl)imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(4-methoxyphenoxy)pyridin-4-yl]imidazole;

- 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(4-fluorophenoxy)pyridin-4-yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-methoxyphenoxy)pyrimidin-4-yl]-
imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-fluorophenoxy)pyrimidin-4-yl]imidazole;
5 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-aminocarbonylphenoxy)pyrimidin-4-yl]-
imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-ethylphenoxy)pyrimidin-4-yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-benzyloxyphenoxy)pyrimidin-4-yl]-
imidazole;
10 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-cyanophenoxy)pyrimidin-4-yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-hydroxyphenoxy)pyrimidin-4-
yl]imidazole;
1-(4-Hydroxycyclohexyl)-4-(4-fluorophenyl)-5-[2-(phenoxy)pyrimidin-4-
yl]imidazole;
15 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(2,6-dimethylphenoxy)pyridin-4-
yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-methylphenoxy)pyridin-4-yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-chlorophenoxy)pyridin-4-yl]imidazole;
1-[3-(N-Morpholino)propyl]-4-(4-fluorophenyl)-5-[2-(phenoxy)pyrimidin-4-
20 yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3-methoxyphenoxy)pyrimidin-4-
yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-phenylphenoxy)pyrimidin-4-
yl]imidazole;
25 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-phenoxyphenoxy)pyrimidin-4-
yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3-hydroxyphenoxy)pyrimidin-4-
yl]imidazole;
1-(3-(N-Morpholino)propyl)-4-(4-fluorophenyl)-5-[2-(4-fluorophenoxy)pyrimidin-4-
30 yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(2-hydroxyphenoxy)pyrimidin-4-
yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3,4-methylenedioxyphenoxy)-
pyrimidin-4-yl]imidazole;
35 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3-fluorophenoxy)pyrimidin-4-
yl]imidazole;
1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(2-fluorophenoxy)pyrimidin-4-

- yl]imidazole;
 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(2-methoxyphenoxy)pyrimidin-4-yl]imidazole;
 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3-trifluoromethylphenoxy)pyrimidin-4-yl]imidazole;
 5 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(3,4-difluorophenoxy)pyrimidin-4-yl]imidazole;
 1-(Piperidin-4-yl)-4-(4-fluorophenyl)-5-[2-(4-methylsulfonylphenoxy)pyrimidin-4-yl]imidazole;
 10 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-thiophenoxypyrimidin-4-yl)imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(1-methyltetrazol-5-ylthio)pyridin-4-yl]imidazole
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[(2-acetamidophenoxy)pyrimidin-4-yl]imidazole;
 15 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[(3-propionamidophenoxy)pyrimidin-4-yl]imidazole;
 1-Cyclohexyl-4-(4-fluorophenyl)-5-[(2-phenoxy)pyrimidin-4-yl]imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(2,6-dimethylphenoxy)pyrimidin-4-yl]imidazole;
 20 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(2-methylphenoxy)pyrimidin-4-yl]imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(2,6-dimethyl-4-chlorophenoxy)-pyrimidin-4-yl]imidazole;
 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(indol-4-yloxy)pyrimidin-4-yl]imidazole;
 25 1-Cyclopropyl-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 1-Isopropyl-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 1-Cyclopentyl-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 (+/-)-1-(1-Hydroxyprop-2-yl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)-imidazole;
 30 3-[4-(4-Fluorophenyl)-5-[(2-phenoxy)pyrimidin-4-yl]imidazol-1-yl]propionitrile;
 (R)-(1-Hydroxy-3-phenylprop-2-yl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 (S)-(1-Hydroxy-3-phenylprop-2-yl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)imidazole;
 35 (+/-)-1-(1-Phenoxyprop-2-yl)-4-(4-fluorophenyl)-5-(2-phenoxy)pyrimidin-4-yl)-imidazole;

- 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(3-piperazin-1-ylacetamido)phenoxy-pyrimidin-4-yl]imidazole;
- 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-[2-(3-piperazin-1-ylamidophenoxy)-pyrimidin-4-yl]imidazole;
- 5 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-isopropoxy-4-pyrimidinyl)imidazole;
- 1-(4-Piperidinyl)-4-(4-fluorophenyl)-5-(2-methoxy-4-pyrimidinyl)imidazole;
- 5-(2-Hydroxy-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
- 5-(2-Methoxy-4-pyridinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
- 5-(2-*iso*-Propoxy-4-pyridinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
- 10 5-(2-Methylthio-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
- 5-(2-Methylthio-4-pyrimidinyl)-4-(4-fluorophenyl)-1-[(1-methyl-4-piperidinyl)imidazole];
- 5-(2-Ethoxy-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole;
- 1-(1-Ethylcarboxylpiperidin-4-yl)-3-(4-thiomethylphenyl)-5-[2-(thiomethyl)-pyrimidin-4-yl]imidazole;
- 15 1-(1-Ethylcarbonylpiperidin-4-yl)-4-(4-methylsulfinylphenyl)-5-[2-methylsulfinyl-pyrimidin-4-yl]imidazole; or
- pharmaceutically acceptable salts thereof.

20 METHODS OF TREATMENT

The cytokine inhibitor compounds, in particular those of Formula (I) or a pharmaceutically acceptable salt, can be used in the manufacture of a medicament for the prophylactic treatment or management of excessive, undesired or inappropriate uterine activity in a mammal, preferably a human, which activity is exacerbated or caused by

25 excessive or unregulated cytokine production by such mammal.

The cytokine inhibitors of the p38/CSPB pathway are capable of inhibiting proinflammatory cytokines, such as IL-1, IL-6, IL-8 and TNF.

The cytokine inhibitors of the p38/CSPB pathway are administered in an amount sufficient to inhibit the cytokine, in particular IL-1, IL-6, IL-8 or TNF, production such that

30 it is regulated down to normal levels, or in some cases to subnormal levels, so as to ameliorate or prevent the disease state. Abnormal levels of IL-1, IL-6, IL-8 or TNF, for instance in the context of the present invention, constitute: (i) levels of free (not cell bound) IL-1, IL-6, IL-8 or TNF greater than or equal to 1 picogram per ml; (ii) any cell associated IL-1, IL-6, IL-8 or TNF; or (iii) the presence of IL-1, IL-6, IL-8 or TNF mRNA above

35 basal levels in cells or tissues in which IL-1, IL-6, IL-8 or TNF, respectively, is produced.

As used herein, the term "inhibiting the production of IL-1 (IL-6, IL-8 or TNF)" refers to:

a) a decrease of excessive *in vivo* levels of the cytokine (IL-1, IL-6, IL-8 or TNF) in a human to normal or sub-normal levels by inhibition of the *in vivo* release of the cytokine by all cells, including but not limited to monocytes or macrophages;

5 b) a down regulation, at the genomic level, of excessive *in vivo* levels of the cytokine (IL-1, IL-6, IL-8 or TNF) in a human to normal or sub-normal levels;

c) a down regulation, by inhibition of the direct synthesis of the cytokine (IL-1, IL-6, IL-8 or TNF) as a postranslational event; or

d) a down regulation, at the translational level, of excessive *in vivo* levels of the cytokine (IL-1, IL-6, IL-8 or TNF) in a human to normal or sub-normal levels.

10 As used herein, the term "cytokine" refers to any secreted polypeptide that affects the functions of cells and is a molecule which modulates interactions between cells in the immune, inflammatory or hematopoietic response. A cytokine includes, but is not limited to, monokines and lymphokines, regardless of which cells produce them. For instance, a monokine is generally referred to as being produced and secreted by a mononuclear cell,
15 such as a macrophage and/or monocyte. Many other cells, however, also produce monokines, such as natural killer cells, fibroblasts, basophils, neutrophils, endothelial cells, brain astrocytes, bone marrow stromal cells, epidermal keratinocytes and B-lymphocytes. Lymphokines are generally referred to as being produced by lymphocyte cells. Examples of cytokines include, but are not limited to, Interleukin-1 (IL-1), Interleukin-6 (IL-6),
20 Interleukin-8 (IL-8), Tumor Necrosis Factor-alpha (TNF- α) and Tumor Necrosis Factor beta (TNF- β).

As used herein, the term "cytokine interfering" or "cytokine suppressive amount" refers to an effective amount of a compound of Formula (I) which will cause a decrease in the *in vivo* levels of the cytokine to normal or sub-normal levels, when given to a patient
25 for the prophylaxis or treatment of a disease state which is exacerbated by, or caused by, excessive or unregulated cytokine production.

The MAP kinase family, alternatively termed CSBP, p38, or RK, has been identified independently by several laboratories. Activation of this novel protein kinase via dual phosphorylation has been observed in different cell systems upon stimulation by a wide
30 spectrum of stimuli, such as physiochemical stress and treatment with lipopolysaccharide or proinflammatory cytokines such as IL-1 and TNF. The cytokine biosynthesis inhibitors for use in the present invention, for instance compounds of Formula (I), have been determined to be potent and selective inhibitors of this CSBP/p38/RK kinase activity. These inhibitors are of aid in determining the signaling pathways involvement in inflammatory responses. In
35 particular, for the first time a definitive signal transduction pathway can be prescribed to the action of lipopolysaccharide in cytokine production in macrophages. The CSBP protein is described in detail in Patent Application USSN 08/123175 Lee et al., filed September 1993;

Lee et al., PCT/US94/10529 filed 16 September 1994; USSN 08/605002, filed 15 April 1996; USSN 08/469421, USSN 08/468902; and Lee et al., *Nature* 300, n(72), 739-746 (Dec. 1994). Inhibitors of the variants and homologs of the CSBP protein are also considered as another aspect of the present invention. One such variant is the p38 beta protein, as described in Jiang, Y., et al., *J. Biol. Chem.*, 271, pp 17920-26 (1996); and variants in USSN 08/746788, filed 15 November 1996; whose disclosures are incorporated by reference in their entirety herein.

Intracellular signal transduction is the means by which cells respond to extracellular stimuli. Regardless of the nature of the cell surface receptor (e.g. protein tyrosine kinase or seven-transmembrane G-protein coupled), protein kinases and phosphatases along with phospholipases are the essential machinery by which the signal is further transmitted within the cell [Marshall, J. C. *Cell*, 80, 179-278 (1995)]. Protein kinases can be categorized into five classes with the two major classes being, tyrosine kinases and serine / threonine kinases depending upon whether the enzyme phosphorylates its substrate(s) on specific tyrosine(s) or serine / threonine(s) residues [Hunter, T., *Methods in Enzymology (Protein Kinase Classification)* p. 3, Hunter, T.; Sefton, B. M.; eds. vol. 200, Academic Press; San Diego, 1991].

For most biological responses, multiple intracellular kinases are involved and an individual kinase can be involved in more than one signaling event. These kinases are often cytosolic and can translocate to the nucleus or the ribosomes where they can affect transcriptional and translational events, respectively. The involvement of kinases in transcriptional control is presently much better understood than their effect on translation as illustrated by the studies on growth factor induced signal transduction involving MAP/ERK kinase [Marshall, C. J. *Cell*, 80, 179 (1995); Herskowitz, I. *Cell*, 80, 187 (1995); Hunter, T. *Cell*, 80, 225 (1995); Seger, R., and Krebs, E. G. *FASEB J.*, 726-735 (1995)].

While many signaling pathways are part of cell homeostasis, numerous cytokines (e.g., IL-1 and TNF) and certain other mediators of inflammation (e.g., COX-2, and iNOS) are produced only as a response to stress signals such as bacterial lipopolysaccharide (LPS). The first indications suggesting that the signal transduction pathway leading to LPS-induced cytokine biosynthesis involved protein kinases came from studies of Weinstein [Weinstein, *et al.*, *J. Immunol.* 151, 3829(1993)] but the specific protein kinases involved were not identified. Working from a similar perspective, Han [Han, *et al.*, *Science*, 265, 808(1994)] identified murine p38 as a kinase which is tyrosine phosphorylated in response to LPS. Definitive proof of the involvement of the p38 kinase in LPS-stimulated signal transduction pathway leading to the initiation of proinflammatory cytokine

biosynthesis was provided by the independent discovery of p38 kinase by Lee [Lee; *et al.*, Nature, 372, 739(1994)] as the molecular target for a novel class of anti-inflammatory agents. The discovery of p38 (termed by Lee as CSBP 1 and 2) provided a mechanism of action of a class of anti-inflammatory compounds for which SK&F 86002 was the prototypic example. These compounds inhibited IL-1 and TNF synthesis in human monocytes at concentrations in the low uM range [Lee, *et al.*, Int. J. Immunopharmac. 10(7), 835(1988)] and exhibited activity in animal models which are refractory to cyclooxygenase inhibitors [Lee; *et al.*, Annals N. Y. Acad. Sci., 696, 149(1993)].

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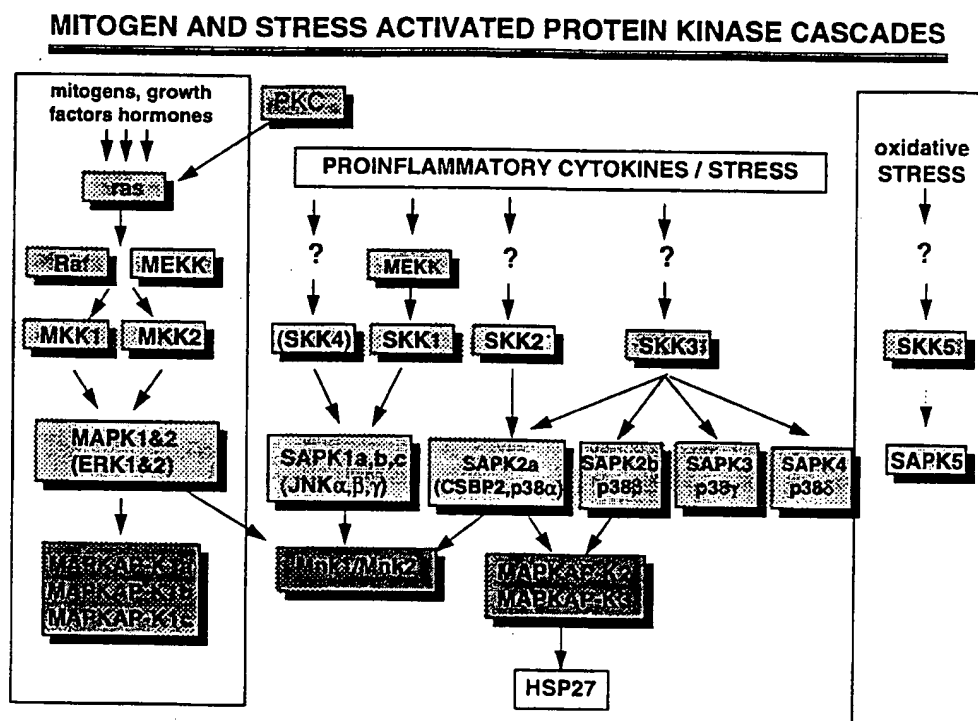


Figure 1

It is now firmly established that CSBP/p38 is a one of several kinases involved in a stress-response signal transduction pathway which is parallel to and largely independent of the analogous mitogen-activated protein kinase (MAP) kinase cascade (Figure 1). Stress signals, including LPS, pro-inflammatory cytokines, oxidants, UV light and osmotic stress, activate kinases upstream from CSBP/p38 which in turn phosphorylate CSBP/p38 at threonine 180 and tyrosine 182 resulting in CSBP/p38 activation. MAPKAP kinase-2 and MAPKAP kinase-3 have been identified as downstream substrates of CSBP/p38 which in turn phosphorylate heat shock protein Hsp 27 (Figure 2). It is not yet known whether MAPKAP-2, MAPKAP-3, Mnk1 or Mnk2 are involved in cytokine biosynthesis or alternatively that inhibitors of

20

CSBP/p38 kinase might regulate cytokine biosynthesis by blocking a yet unidentified substrate downstream from CSBP/p38 [Cohen, P. Trends Cell Biol., 353-361(1997)].

p38 Kinase Pathway

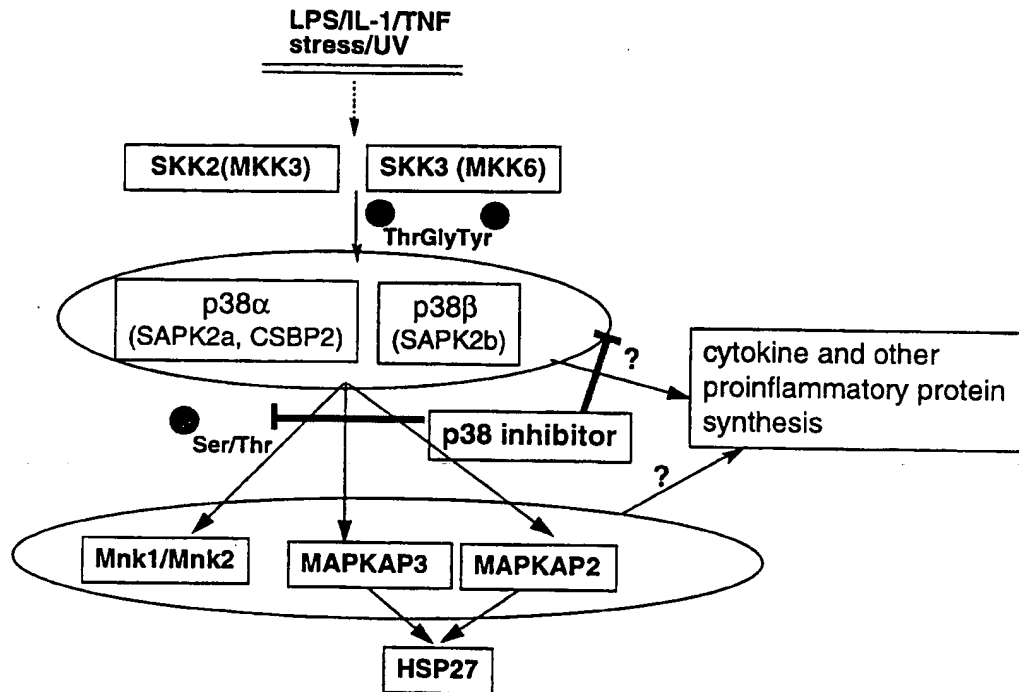


Figure 2

What is known, however, is that in addition to inhibiting IL-1 and TNF, CSBP/p38 kinase inhibitors (SK&F 86002 and SB 203580) also decrease the synthesis of a wide variety of pro-inflammatory proteins including, IL-6, IL-8, GM-CSF and COX-2. Inhibitors of CSBP/p38 kinase have also been shown to suppress the TNF-induced expression of VCAM-1 on endothelial cells, the TNF-induced phosphorylation and activation of cytosolic PLA2 and the IL-1-stimulated synthesis of collagenase and stromelysin. These and additional data demonstrate that CSBP/p38 is involved not only cytokine synthesis, but also in cytokine signaling [CSBP/P38 kinase reviewed in Cohen, P. Trends Cell Biol., 353-361(1997)].

Pharamaceutical Formulations

The cytokine biosynthesis inhibitors for use in the present invention will normally be formulated into a pharmaceutical composition in accordance with standard pharmaceutical practice, for example they will be formulated with a pharmaceutically

acceptable diluent or carrier. Cytokine biosynthesis inhibitors, and pharmaceutically acceptable salts thereof, and pharmaceutical compositions incorporating such may conveniently be administered by any of the routes conventionally used for drug administration, for instance, orally, topically, parenterally or by inhalation. The cytokine biosynthesis inhibitors may be administered in conventional dosage forms prepared by combining a cytokine biosynthesis inhibitor with standard pharmaceutical carriers according to conventional procedures. Cytokine biosynthesis inhibitors may also be administered in conventional dosages in combination with a known, second therapeutically active compound. These procedures may involve mixing, granulating and compressing or dissolving the ingredients as appropriate to the desired preparation. It will be appreciated that the form and character of the pharmaceutically acceptable character or diluent is dictated by the amount of active ingredient with which it is to be combined, the route of administration and other well-known variables. The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof.

The pharmaceutical carrier employed may be, for example, either a solid or liquid. Exemplary of solid carriers are lactose, terra alba, sucrose, talc, gelatin, agar, pectin, acacia, magnesium stearate, stearic acid and the like. Exemplary of liquid carriers are syrup, peanut oil, olive oil, water and the like. Similarly, the carrier or diluent may include time delay material well known to the art, such as glyceryl mono-stearate or glyceryl distearate alone or with a wax.

A wide variety of pharmaceutical forms can be employed. Thus, if a solid carrier is used, the preparation can be tableted, placed in a hard gelatin capsule in powder or pellet form or in the form of a troche or lozenge. The amount of solid carrier will vary widely but preferably will be from about 25mg to about 1g. When a liquid carrier is used, the preparation will be in the form of a syrup, emulsion, soft gelatin capsule, sterile injectable liquid such as an ampule or nonaqueous liquid suspension.

The cytokine biosynthesis inhibitors may be administered topically, that is by non-systemic administration. This includes the application of an inhibitor externally to the epidermis or the buccal cavity and the instillation of such a compound into the ear, eye and nose, such that the compound does not significantly enter the blood stream. In contrast, systemic administration refers to oral, intravenous, intraperitoneal and intramuscular administration.

Formulations suitable for topical administration include liquid or semi-liquid preparations suitable for penetration through the skin to the site of inflammation such as liniments, lotions, creams, ointments or pastes, and drops suitable for administration to the eye, ear or nose. The active ingredient may comprise, for topical administration, from

0.001% to 10% w/w, for instance from 1% to 2% by weight of the formulation. It may however comprise as much as 10% w/w but preferably will comprise less than 5% w/w, more preferably from 0.1% to 1% w/w of the formulation.

5 Lotions according to the present invention include those suitable for application to the skin or eye. An eye lotion may comprise a sterile aqueous solution optionally containing a bactericide and may be prepared by methods similar to those for the preparation of drops. Lotions or liniments for application to the skin may also include an agent to hasten drying and to cool the skin, such as an alcohol or acetone, and/or a moisturizer such as glycerol or an oil such as castor oil or arachis oil.

10 Creams, ointments or pastes according to the present invention are semi-solid formulations of the active ingredient for external application. They may be made by mixing the active ingredient in finely-divided or powdered form, alone or in solution or suspension in an aqueous or non-aqueous fluid, with the aid of suitable machinery, with a greasy or non-greasy base. The base may comprise hydrocarbons such as hard, soft or
15 liquid paraffin, glycerol, beeswax, a metallic soap; a mucilage; an oil of natural origin such as almond, corn, arachis, castor or olive oil; wool fat or its derivatives or a fatty acid such as steric or oleic acid together with an alcohol such as propylene glycol or a macrogel. The formulation may incorporate any suitable surface active agent such as an anionic, cationic or non-ionic surfactant such as a sorbitan ester or a polyoxyethylene derivative thereof.
20 Suspending agents such as natural gums, cellulose derivatives or inorganic materials such as siliceous silicas, and other ingredients such as lanolin, may also be included.

Drops according to the present invention may comprise sterile aqueous or oily solutions or suspensions and may be prepared by dissolving the active ingredient in a suitable aqueous solution of a bactericidal and/or fungicidal agent and/or any other suitable
25 preservative, and preferably include a surface active agent. The resulting solution may then be clarified by filtration, transferred to a suitable container which is then sealed and sterilized by autoclaving or maintaining at 98-100°C for half an hour. Alternatively, the solution may be sterilized by filtration and transferred to the container by an aseptic technique. Examples of bactericidal and fungicidal agents suitable for inclusion in the
30 drops are phenylmercuric nitrate or acetate (0.002%), benzalkonium chloride (0.01%) and chlorhexidine acetate (0.01%). Suitable solvents for the preparation of an oily solution include glycerol, diluted alcohol and propylene glycol.

The cytokine biosynthesis inhibitors may be administered parenterally, that is by intravenous, intramuscular, subcutaneous intranasal, intrarectal, intravaginal or
35 intraperitoneal administration. The subcutaneous and intramuscular forms of parenteral administration are generally preferred. Appropriate dosage forms for such administration may be prepared by conventional techniques. The cytokine biosynthesis inhibitors may

also be administered by inhalation, that is by intranasal and oral inhalation administration. Appropriate dosage forms for such administration, such as an aerosol formulation or a metered dose inhaler, may be prepared by conventional techniques.

For all methods of use disclosed herein for the cytokine biosynthesis inhibitors, including compounds of Formula (I), the preferred, dosage regimen would be parenteral until contractions cease, and then as long as necessary to optimise fetal well-being prior to delivery, i.e. as near to term (37 weeks gestation) as is necessary. In light of this, daily parenteral dosage regimen will be from about 0.1 to about 80 mg/kg of total body weight, preferably from about 0.2 to about 30 mg/kg, and more preferably from about 0.5 mg to 15mg/kg. The daily oral dosage regimen will preferably be from about 0.1 to about 80 mg/kg of total body weight, preferably from about 0.2 to 30 mg/kg, more preferably from about 0.5 mg to 15mg. The daily topical dosage regimen, such as may be applied to prevent cervical ripening, could be administered topically to the cervix to prevent cervical softening and delay fetal membrane rupture. Such as topical dosage will preferably be in a formulation containing from 0.1 mg to 150 mg, administered one to four, preferably two or three times daily. The daily inhalation dosage regimen, if applicable, will preferably be from about 0.01 mg/kg to about 1 mg/kg per day.

It will also be recognized by one of skill in the art that the optimal quantity and spacing of individual dosages of cytokine biosynthesis inhibitor will be determined by the nature and extent of the condition being treated, the form, route and site of administration, and the particular patient being treated, and that such optimums can be determined by conventional techniques. It will also be appreciated by one of skill in the art that the optimal course of treatment, i.e., the number of doses given per day for a defined number of days, can be ascertained by those skilled in the art using conventional course of treatment determination tests.

BIOLOGICAL EXAMPLES

The cytokine-inhibiting effects of compounds for use in the present invention, such as those noted above, may be determined by the following *in vitro* assays:

Assays for Interleukin-1 (IL-1), Interleukin-8 (IL-8), and Tumour Necrosis Factor (TNF) are well known in the art, and may be found in a number of publications, and patents. Representative suitable assays for use herein are described in Adams et al., US 5,593,992, whose disclosure is incorporated by reference in its entirety.

Interleukin - 1 (IL-1)

Human peripheral blood monocytes are isolated and purified from either fresh blood preparations from volunteer donors, or from blood bank buffy coats, according to the

procedure of Colotta *et al.*, *J Immunol*, **132**, 936 (1984). These monocytes (1×10^6) are plated in 24-well plates at a concentration of 1-2 million/ml per well. The cells are allowed to adhere for 2 hours, after which time non-adherent cells are removed by gentle washing. Test compounds are then added to the cells for 1h before the addition of lipopolysaccharide (50 ng/ml), and the cultures are incubated at 37°C for an additional 24h. At the end of this period, culture supernatants are removed and clarified of cells and all debris. Culture supernatants are then immediately assayed for IL-1 biological activity, either by the method of Simon *et al.*, *J. Immunol. Methods*, **84**, 85, (1985) (based on ability of IL-1 to stimulate a Interleukin 2 producing cell line (EL-4) to secrete IL-2, in concert with A23187 ionophore) or the method of Lee *et al.*, *J. ImmunoTherapy*, **6** (1), 1-12 (1990) (ELISA assay).

In vivo TNF assay:

- (1) Griswold *et al.*, *Drugs Under Exp. and Clinical Res.*, **XIX** (6), 243-248 (1993); or
- (2) Boehm, *et al.*, *Journal Of Medicinal Chemistry* **39**, 3929-3937 (1996) whose disclosures are incorporated by reference herein in their entirety.

LPS-induced TNF α Production in Mice and Rats

In order to evaluate in vivo inhibition of LPS-induced TNF α production in rodents, both mice and rats are injected with LPS.

Mouse Method

Male Balb/c mice from Charles River Laboratories are pretreated (30 minutes) with compound or vehicle. After the 30 min. pretreat time, the mice are given LPS (lipopolysaccharide from *Escherichia coli* Serotype 055-85, Sigma Chemical Co., St Louis, MO) 25 ug/mouse in 25 ul phosphate buffered saline (pH 7.0) intraperitoneally. Two hours later the mice are killed by CO₂ inhalation and blood samples are collected by exsanguination into heparinized blood collection tubes and stored on ice. The blood samples are centrifuged and the plasma collected and stored at -20°C until assayed for TNF α by ELISA.

Rat Method

Male Lewis rats from Charles River Laboratories are pretreated at various times with compound or vehicle. After a determined pretreat time, the rats are given LPS (lipopolysaccharide from *Escherichia coli* Serotype 055-85, Sigma Chemical Co., St Louis, MO) 3.0 mg/kg intraperitoneally. The rats are killed by CO₂ inhalation and heparinized whole blood is collected from each rat by cardiac

puncture 90 minutes after the LPS injection. The blood samples are centrifuged and the plasma collected for analysis by ELISA for TNF α levels.

ELISA Method

5 TNF α levels were measured using a sandwich ELISA, as described in Olivera et al., Circ. Shock, 37, 301-306, (1992), whose disclosure is incorporated by reference in its entirety herein, using a hamster monoclonal antimurine TNF α (Genzyme, Boston, MA) as the capture antibody and a polyclonal rabbit antimurine TNF α (Genzyme) as the second antibody. For detection, a peroxidase-conjugated goat
10 antirabbit antibody (Pierce, Rockford, IL) was added, followed by a substrate for peroxidase (1 mg/ml orthophenylenediamine with 1% urea peroxide). TNF α levels in the plasma samples from each animal were calculated from a standard curve generated with recombinant murine TNF α (Genzyme).

15 **LPS-Stimulated Cytokine Production in Human Whole Blood**

Assay: Test compound concentrations were prepared at 10 X concentrations and LPS prepared at 1 ug/ml (final conc. of 50 ng/ml LPS) and added in 50 uL volumes to 1.5 mL eppendorf tubes. Heparinized human whole blood was obtained from healthy volunteers and was dispensed into eppendorf tubes containing compounds
20 and LPS in 0.4 mL volumes and the tubes incubated at 37 C. Following a 4 hour incubation, the tubes were centrifuged at 5000 rpm for 5 minutes in a TOMY microfuge, plasma was withdrawn and frozen at -80 C.

Cytokine measurement: IL-1 and/or TNF were quantified using a standardized
25 ELISA technology. An in-house ELISA kit was used to detect human IL-1 and TNF. Concentrations of IL-1 or TNF were determined from standard curves of the appropriate cytokine and IC50 values for test compound (concentration that inhibited 50% of LPS-stimulated cytokine production) were calculated by linear regression analysis.

30

Cytokine Specific Binding Protein Assay

A radiocompetitive binding assay was developed to provide a highly reproducible primary screen for structure-activity studies. This assay provides many advantages over the conventional bioassays which utilize freshly isolated human
35 monocytes as a source of cytokines and ELISA assays to quantify them. Besides being a much more facile assay, the binding assay has been extensively validated to highly correlate with the results of the bioassay. A specific and reproducible cytokine

inhibitor binding assay was developed using soluble cytosolic fraction from THP.1 cells and a radiolabeled compound. Patent Application USSN 08/123175 Lee et al., filed September 1993, US 5,783,644 and US 5,777,097 Lee et al., WO94/10529 filed 16 September 1994 and Lee et al., *Nature* 300, n(72), 739-746 (Dec. 1994) whose disclosures are incorporated by reference herein in its entirety describes the above noted method for screening drugs to identify compounds which interact with and bind to the cytokine specific binding protein (hereinafter CSBP). However, for purposes herein the binding protein may be in isolated form in solution, or in immobilized form, or may be genetically engineered to be expressed on the surface of recombinant host cells such as in phage display system or as fusion proteins. Alternatively, whole cells or cytosolic fractions comprising the CSBP may be employed in the screening protocol. Regardless of the form of the binding protein, a plurality of compounds are contacted with the binding protein under conditions sufficient to form a compound/binding protein complex and compound capable of forming, enhancing or interfering with said complexes are detected.

CSBP/p38 Kinase Assay:

This assay measures the CSBP/p38-catalyzed transfer of ^{32}P from [α - ^{32}P]ATP to threonine residue in an epidermal growth factor receptor (EGFR)-derived peptide (T669) with the following sequence: KRELVEPLTPSGEAPNQALLR (residues 661-681). (See Gallagher *et al.*, "Regulation of Stress Induced Cytokine Production by Pyridinyl Imidazoles: Inhibition of CSBP Kinase", *BioOrganic & Medicinal Chemistry*, 1997, 5, 49-64).

Reactions were carried in round bottom 96 well plate (from Corning) in a 30 ml volume. Reactions contained (in final concentration): 25 mM Hepes, pH7.5; 8 mM MgCl_2 ; 0.17 mM ATP (the $K_m[\text{ATP}]$ of p38 (see Lee et al., *Nature* 300, n72 pg 639-746 (Dec. 1994)); 2.5 μCi of [γ - ^{32}P]ATP; 0.2 mM sodium orthovanadate; 1 mM DTT; 0.1% BSA; 10% glycerol; 0.67 mM T669 peptide; and 2-4 nM of yeast-expressed, activated and purified p38. Reactions were initiated by the addition of [γ - ^{32}P]Mg/ATP, and incubated for 25 min. at 37 °C. Inhibitors (dissolved in DMSO) were incubated with the reaction mixture on ice for 30 minutes prior to adding the ^{32}P -ATP. Final DMSO concentration was 0.16%. Reactions were terminated by adding 10 μl of 0.3 M phosphoric acid, and phosphorylated peptide was isolated from the reactions by capturing it on p81 phosphocellulose filters. Filters were washed with 75 mM phosphoric acids, and incorporated ^{32}P was quantified using beta scintillation counter. Under these conditions, the specific activity of p38 was 400-450 pmol/pmol enzyme, and the activity was linear for up to

2 hr of incubation. The kinase activity values were obtained after subtracting values generated in the absence of substrate which were 10-15% of total values.

Modulation of PGE₂ and IL-1 β production

5 The Examples below determine the effects of the CSAID™ compounds on the ability to modulate both PGE₂ and IL-1 β production from fetal membranes.

Fetal membranes were obtained from term elective caesarean sections from uncomplicated pregnancies and washed in phosphate buffered saline containing 10% penicillin, streptomycin and L-glutamine. Whole membrane
10 discs consisting of adherent amnion and chorio-decidua each measuring 1.5 cm were then cut and incubated overnight in multiwell tissue culture plates at 37°C, 95% air, 5% CO₂ in serum free medium 199 (Sigma) supplemented with insulin, transferrin and selenium. Following the addition of fresh medium 199 four experimental groups (A to D) were set up. Each experimental group consisted
15 of identical triplicate tissue culture wells.

<u>Group</u>	<u>Medium</u>
A	Control (Unstimulated)
B	Control (Unstimulated) + SKF86002
20 C	LPS
D	LPS + SKF 86002

LPS (Sigma-E.coli Serotype 0114:B4) was used at a concentration of 10⁻⁸ g/dl. SKF 86002 was dissolved in ethanol to provide a final concentration of 10 μ M.

25 Group A consisted of control discs incubated in medium alone. Incubations were carried out for four, eight and twelve hours following which the supernatants were harvested and stored at -20°C for subsequent estimation of IL-1 β and PGE₂ levels by ELISA {enzyme linked immunosorbent assay (Amersham)}.

30 Control wells consisting of ethanol and medium 199 with and without LPS were also included. Fetal membrane viability was assessed using the diaphorase histochemical method, see Aldred L.F., et al. (1983) *J. Steroid Biochem.*, 18, 411-414.

35

RESULTS: IL-1 β production:

Mixed model analysis of variance was used to analyse the data. The assumptions of the analysis of variance were checked and a log transformation was found to be the most appropriate. Data is presented on an untransformed original scale for ease of interpretation.

5

Group:

Group A v Group B $p=0.007$

Difference = 25.5 95% CI (-2.3, 53.3)

10 Group C v Group D $p=0.002$

Difference 45.5 95% CI (17.9, 73.2)

Time:

4 hours v 12 hours $p=0.08$

15 Difference 22.7 95% CI (-3.0, 48.4)

PGE₂ production:

Mixed model analysis of variance was used to analyse the data. The assumptions of the analysis of variance were checked and a log transformation was found to be the most appropriate. Data is presented on an untransformed scale for ease of interpretation.

20

Group:

Group A v Group B $p<0.001$

25 Difference 109 95% CI (78.96, 139.9)

Group C v Group D $p<0.001$

Difference 161 95% CI (130.6, 191.9)

30 Tissue viability was not compromised by the addition of the drug as tested by the diaphorase method. Ethanol alone did not significantly inhibit production of either PGE₂ or IL-1 β from the fetal membranes.

Conclusions

35 The results indicate that following treatment with the prototype CSAID™ compound SKF 86002 [6-(4-fluorophenyl)-2,3-dihydro-5-(4-

pyridinyl)imidazo[2,1-b]thiazole] there was a significant decrease in the production of both PGE₂ and IL-1 β from fetal membranes.

5 SKF 86002 reduced IL-1 β production from both control (p=0.07) and LPS stimulated wells (p=0.002). The effects of the agent appeared to diminish after 12 hours incubation. Maximal production of IL-1 β from all treatment groups occurred after 8 hours incubation. IL-1 β production was significantly lower at 12 hours compared to 4 hours in all treatment groups (p=0.08). SKF86002 reduced PGE₂ production from both control (p<0.001) and LPS stimulated wells (p<0.001). The effects did not seem to diminish throughout the incubation period.

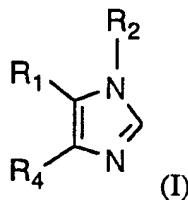
10 This data indicates that CSAID™ compounds have utility to modulate prostaglandin and interleukin production from gestational tissues. As the compound decreased basal PGE₂ and IL-1 β production as well as production in response to LPS, this provides a basis for treatment of both infection driven and idiopathic pre-term labour.

20 All publications, including but not limited to patents and patent applications, cited in this specification are herein incorporated by reference as if each individual publication were specifically and individually indicated to be incorporated by reference herein as though fully set forth.

25 The above description fully discloses the invention including preferred embodiments thereof. Modifications and improvements of the embodiments specifically disclosed herein are within the scope of the following claims. Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. Therefore the Examples herein are to be construed as merely illustrative and not a limitation of the scope of the present invention in any way. The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

What is Claimed is:

1. A method of prophylactic treatment or management of excessive, undesired or inappropriate uterine activity in a mammal, which method comprises
 5 administering to said mammal an effective amount of a compound which inhibits the production, transcription or translation of a cytokine.
2. The method according to Claim 1 wherein the cytokine is inhibited by inhibition of the kinase CSBP/p38/RK.
 10
3. The method according to Claim 1 or 2 wherein the uterine activity is pre-term labour which is infection driven.
4. The method according to Claim 1 or 2 wherein the uterine activity is
 15 idiopathic pre-term labour.
5. The method according to Claim 1 or 2 wherein the uterine activity is unwanted dilatation, or ripening of the cervix.
- 20 6. The method according to Claim 1 or 2 wherein the uterine activity is preterm rupture of the fetal membrane.
7. The method according to Claim 1 or 2 wherein the uterine activity is eclampsia or pre-eclampsia.
 25
8. The method according to any one of the preceding claims wherein the compound is of the formula (I):



30 wherein:

R₁ is a pyrid-4-yl, pyrimidin-4-yl, pyridazin-4-yl, 1,2,4-triazin-5-yl, quinol-4-yl, isoquinolinyl, quinazolin-4-yl, 1-imidazolyl or 1-benzimidazolyl ring, which ring is optionally substituted independently one to three times with Y, NHR_a, optionally substituted C₁₋₄ alkyl, halogen, hydroxyl, optionally substituted C₁₋₄ alkoxy,

optionally substituted C₁₋₄ alkylthio, C₁₋₄ alkylsulfinyl, CH₂OR₁₂, amino, mono and di- C₁₋₆ alkyl substituted amino, or N(R₁₀)C(O)R_b;

Y is O-R_a;

R₄ is phenyl, naphth-1-yl or naphth-2-yl, or heteroaryl, which is optionally substituted by one or two substituents, each of which is independently selected, and which, for a 4-phenyl, 4-naphth-1-yl, 5-naphth-2-yl or 6-naphth-2-yl substituent, is halogen, cyano, nitro, C(Z)NR₇R₁₇, C(Z)OR₁₆, (CR₁₀R₂₀)_vCOR₁₂, SR₅, SOR₅, OR₁₂, halo-substituted-C₁₋₄ alkyl, C₁₋₄ alkyl, ZC(Z)R₁₂, NR₁₀C(Z)R₁₆, or (CR₁₀R₂₀)_vNR₁₀R₂₀, and which, for other positions of substitution, is halogen, cyano, C(Z)NR₁₃R₁₄, C(Z)OR₃, (CR₁₀R₂₀)_m"COR₃, S(O)_mR₃, OR₃, halo-substituted-C₁₋₄ alkyl, C₁₋₄ alkyl, (CR₁₀R₂₀)_m"NR₁₀C(Z)R₃, NR₁₀S(O)_m"R₈, NR₁₀S(O)_m"NR₇R₁₇, ZC(Z)R₃ or (CR₁₀R₂₀)_m"NR₁₃R₁₄;

v is 0, or an integer having a value of 1 or 2;

n is an integer having a value of 1 to 10;

n' is 0, or an integer having a value of 1 to 10;

m is 0, or an integer having a value of 1 or 2;

m' is an integer having a value of 1 or 2,

m" is 0, or an integer having a value of 1 to 5;

R₂ is hydrogen, (CR₁₀R₂₀)_n'OR₉, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, C₁₋₁₀ alkyl, halo-substituted C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₂₋₁₀ alkynyl, C₃₋₇ cycloalkyl, C₃₋₇ cycloalkylC₁₋₁₀ alkyl, C₅₋₇ cycloalkenyl, C₅₋₇ cycloalkenylC₁₋₁₀ alkyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl, heteroarylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nOR₁₁, (CR₁₀R₂₀)_nS(O)_mR₁₈, (CR₁₀R₂₀)_nNHS(O)₂R₁₈, (CR₁₀R₂₀)_nNR₁₃R₁₄, (CR₁₀R₂₀)_nNO₂, (CR₁₀R₂₀)_nCN, (CR₁₀R₂₀)_nSO₂R₁₈, (CR₁₀R₂₀)_nS(O)_m"NR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)R₁₁, (CR₁₀R₂₀)_nOC(Z)R₁₁, (CR₁₀R₂₀)_nC(Z)OR₁₁, (CR₁₀R₂₀)_nC(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nC(Z)NR₁₁OR₉, (CR₁₀R₂₀)_nNR₁₀C(Z)R₁₁, (CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nN(OR₆)C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nN(OR₆)C(Z)R₁₁, (CR₁₀R₂₀)_nC(=NOR₆)R₁₁, (CR₁₀R₂₀)_nNR₁₀C(=NR₁₉)NR₁₃R₁₄, (CR₁₀R₂₀)_nOC(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nNR₁₀C(Z)NR₁₃R₁₄, (CR₁₀R₂₀)_nNR₁₀C(Z)OR₁₀, 5-(R₁₈)-1,2,4-oxadiazol-3-yl or 4-(R₁₂)-5-(R₁₈R₁₉)-4,5-dihydro-1,2,4-oxadiazol-3-yl; wherein the aryl, arylalkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, heteroaryl alkyl, heterocyclyl and heterocyclyl alkyl groups may be optionally substituted;

Z is oxygen or sulfur;

- R_a is a C₁₋₆ alkyl, aryl, arylC₁₋₆ alkyl, heterocyclyl, heterocyclylC₁₋₆ alkyl, heteroaryl, or heteroarylC₁₋₆ alkyl moiety, and wherein each of these moieties may be optionally substituted;
- R_b is hydrogen, C₁₋₆ alkyl, C₃₋₇ cycloalkyl, aryl, arylC₁₋₄ alkyl, heteroaryl, heteroarylC₁₋₄ alkyl, heterocyclyl, or heterocyclylC₁₋₄ alkyl;
- R₃ is heterocyclyl, heterocyclylC₁₋₁₀ alkyl or R₈;
- R₅ is hydrogen, C₁₋₄ alkyl, C₂₋₄ alkenyl, C₂₋₄ alkynyl or NR₇R₁₇, excluding the moieties SR₅ being SNR₇R₁₇ and SOR₅ being SOH;
- R₆ is hydrogen, a pharmaceutically acceptable cation, C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, aryl, arylC₁₋₄ alkyl, heteroaryl, heteroarylC₁₋₄ alkyl, heterocyclyl, aroyl, or C₁₋₁₀ alkanoyl;
- R₇ and R₁₇ is each independently selected from hydrogen or C₁₋₄ alkyl or R₇ and R₁₇ together with the nitrogen to which they are attached form a heterocyclic ring of 5 to 7 members which ring optionally contains an additional heteroatom selected from oxygen, sulfur or NR₁₅;
- R₈ is a C₁₋₁₀ alkyl, halo-substituted C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₂₋₁₀ alkynyl, C₃₋₇ cycloalkyl, C₅₋₇ cycloalkenyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl, heteroarylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nOR₁₁, (CR₁₀R₂₀)_nS(O)_mR₁₈, (CR₁₀R₂₀)_nNHS(O)₂R₁₈, or (CR₁₀R₂₀)_nNR₁₃R₁₄ moiety; wherein the aryl, arylalkyl, heteroaryl, heteroaryl alkyl moieties may be optionally substituted;
- R₉ is hydrogen, C(Z)R₁₁ or optionally substituted C₁₋₁₀ alkyl, S(O)₂R₁₈, optionally substituted aryl or optionally substituted arylC₁₋₄ alkyl;
- R₁₀ and R₂₀ is each independently selected from hydrogen and C₁₋₄ alkyl;
- R₁₁ is hydrogen, C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, aryl, arylC₁₋₁₀ alkyl, heteroaryl or heteroarylC₁₋₁₀ alkyl;
- R₁₂ is hydrogen or R₁₆;
- R₁₃ and R₁₄ is each independently selected from hydrogen, optionally substituted C₁₋₄ alkyl, optionally substituted aryl or optionally substituted arylC₁₋₄ alkyl, or together with the nitrogen to which they are attached R₁₃ and R₁₄ form a heterocyclic ring of 5 to 7 members which ring optionally contains an additional heteroatom selected from oxygen, sulfur or NR₉;
- R₁₅ is R₁₀ or C(Z)-C₁₋₄ alkyl;
- R₁₆ is C₁₋₄ alkyl, halo-substituted-C₁₋₄ alkyl, or C₃₋₇ cycloalkyl;
- R₁₈ is C₁₋₁₀ alkyl, C₃₋₇ cycloalkyl, heterocyclyl, aryl, arylC₁₋₁₀ alkyl, heterocyclyl, heterocyclylC₁₋₁₀ alkyl, heteroaryl or heteroarylC₁₋₁₀ alkyl;
- R₁₉ is hydrogen, cyano, C₁₋₄ alkyl, C₃₋₇ cycloalkyl or aryl; or a pharmaceutically acceptable salt thereof.

9. The method according to Claim 8 wherein R₁ is optionally substituted 4-pyridyl or 4-pyrimindyl.
- 5 10. The method according to Claim 8 or 9 wherein R_a is alkyl, aryl, arylalkyl, halosubstituted arylalkyl, halosubstituted aryl, heterocyclyl alkyl, hydroxyalkyl, alkyl-1-piperidine-carboxylate, heterocyclyl, alkyl substituted heterocyclyl, halosubstituted heterocyclyl, or aryl substituted heterocyclyl.
- 10 11. The method according to Claim 10 wherein R_a is methyl, ethyl, isopropoxy, benzyl, halosubstituted benzyl, naphthylmethyl, phenyl, halosubstituted phenyl, morpholinopropyl, 2-hydroxyethyl, ethyl-1-piperidinecarboxylate, piperonyl, piperidin-4-yl, alkyl substituted piperidine, chlorotryptamine, or tetrathiohydropyranlyl.
- 15 12. The method according to any one of claims 8 to 11 wherein R₄ is optionally substituted phenyl.
13. The method according to Claim 12 wherein the phenyl is substituted in the 4-
20 position by halogen.
14. The method according to any one of claims 8 to 13 wherein R₂ is selected from optionally substituted heterocyclyl, optionally substituted heterocyclylC₁₋₁₀ alkyl, (CR₁₀R₂₀)_nNS(O)₂R₁₈, (CR₁₀R₂₀)_nS(O)_mR₁₈, arylC₁₋₁₀ alkyl,
25 (CR₁₀R₂₀)_nNR₁₃R₁₄, optionally substituted C₃₋₇ cycloalkyl, and optionally substituted C₃₋₇ cycloalkylC₁₋₁₀ alkyl.
15. The method according to Claim 14 wherein R₂ is morpholino propyl, piperidine, N-methylpiperidine, N-benzylpiperidine, 2,2,6,6-tetramethylpiperidine,
30 4-aminopiperidine, 4-amino-2,2,6,6-tetramethyl piperidine, 4-hydroxycyclohexyl, 4-methyl-4-hydroxycyclohexyl, 4-pyrrolinindylcyclohexyl, 4-methyl-4-aminocyclohexyl, 4-methyl-4-acetamidocyclohexyl, 4-ketocyclohexyl, 4-oxiranyl, or 4-hydroxy-4-(1-propynyl)cyclohexyl.
- 35

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03015

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61K31/00 A61K31/44 A61K31/505 A61K31/445 A61K31/535

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CHWALISZ K ET AL: "Cervical ripening with the cytokines interleukin 8, interleukin 1 beta and tumour necrosis factor alpha in guinea-pigs." HUMAN REPRODUCTION, (1994 NOV) 9 (11) 2173-81. JOURNAL CODE: HRP. ISSN: 0268-1161., XP002094115 ENGLAND: United Kingdom see the whole document ---	1,3-6
Y	---	2,8-15
	-/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

19 February 1999

Date of mailing of the international search report

05/03/1999

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Hoff, P

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03015

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ERNY R ET AL: "The effects of oral administration of progesterone for premature labor." AMERICAN JOURNAL OF OBSTETRICS AND GYNECOLOGY, (1986 MAR) 154 (3) 525-9. JOURNAL CODE: 3NI. ISSN: 0002-9378., XP002094116 United States see the whole document ---	1,3,4
X	MIZUTANI S ET AL: "Positive effect of estradiol and progesterone in severe pre-eclampsia." EXPERIMENTAL AND CLINICAL ENDOCRINOLOGY, (1988 DEC) 92 (2) 161-70. JOURNAL CODE: EPA. ISSN: 0232-7384., XP002094117 GERMANY, EAST: German Democratic Republic see the whole document ---	1,7
X	WO 95 07699 A (COLUMBIA LAB INC) 23 March 1995 see page 1, line 1 - line 16 ---	1,3,4,7
A	ITO A ET AL: "Suppression of interleukin 8 production by progesterone in rabbit uterine cervix." BIOCHEMICAL JOURNAL, (1994 JUL 1) 301 (PT 1) 183-6. JOURNAL CODE: 9Y0. ISSN: 0264-6021., XP002094118 ENGLAND: United Kingdom see the whole document ---	1,3,4,7
X	ROMERO R ET AL: "NATURAL INTERLEUKIN-1 RECEPTOR ANTAGONIST BLOCKS INTERLEUKIN-1-INDUCED PROSTAGLANDIN PRODUCTION BY HUMAN INTRAUTERINE TISSUES THE BASIS FOR A NOVEL APPROACH TO THE TREATMENT OF PRETERM LABOR IN THE SETTING OF INFECTION." 12TH ANNUAL MEETING OF THE SOCIETY OF PERINATAL OBSTETRICIANS, ORLANDO, FLORIDA, USA, FEBRUARY 3-8, 1992. AM J OBSTET GYNECOL. (1992) 166 (1 PART 2), 274. CODEN: AJOGAH. ISSN: 0002-9378., XP002094119	1,3,4
Y	see the whole document ---	2,8-15

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03015

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>BRY K ET AL: "Transforming growth factor-beta opposes the stimulatory effects of interleukin -1 and tumor necrosis factor on amnion cell prostaglandin E2 production: implication for preterm labor." AMERICAN JOURNAL OF OBSTETRICS AND GYNECOLOGY, (1992 JUL) 167 (1) 222-6. JOURNAL CODE: 3NI. ISSN: 0002-9378., XP002094120 United States see the whole document</p>	2,8-15
Y	<p>BRY K ET AL: "Transforming growth factor-beta 2 prevents preterm delivery induced by interleukin -1 alpha and tumor necrosis factor-alpha in the rabbit." AMERICAN JOURNAL OF OBSTETRICS AND GYNECOLOGY, (1993 APR) 168 (4) 1318-22 JOURNAL CODE: 3NI. ISSN: 0002-9378., XP002094121 United States see the whole document</p>	2,8-15
Y	<p>MITCHELL M D ET AL: "Immunoendocrinology of preterm labour and delivery." BAILLIERES CLINICAL OBSTETRICS AND GYNAECOLOGY, (1993 SEP) 7 (3) 553-75. REF: 107 JOURNAL CODE: DFO. ISSN: 0950-3552., XP002094122 ENGLAND: United Kingdom cited in the application see the whole document</p>	2,8-15
Y	<p>GALLAGHER T F ET AL: "Regulation of stress -induced cytokine production by pyridinylimidazoles; inhibition of CSBP kinase." BIOORGANIC AND MEDICINAL CHEMISTRY, (1997 JAN) 5 (1) 49-64. JOURNAL CODE: B38. ISSN: 0968-0896., XP002094123 ENGLAND: United Kingdom see the whole document</p>	2,8-15
Y	<p>WO 97 25045 A (SMITHKLINE BEECHAM CORP ;ADAMS JERRY L (US); BOEHM JEFFREY C (US);) 17 July 1997 see abstract; claims; examples see page 31, line 1 - line 7</p>	2,8-15

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03015

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 96 40143 A (SMITHKLINE BEECHAM CORP ;ADAMS JERRY LEROY (US); GALLAGHER TIMOTHY) 19 December 1996 see abstract see page 50, line 14 - line 25; claims; examples ---	2,8-15
Y	WO 96 21654 A (SMITHKLINE BEECHAM CORP ;ADAMS JERRY LEROY (US); GARIGIPATI RAVI S) 18 July 1996 see abstract see page 35, line 18 - page 36, line 2; claims; examples ---	2,8-15
Y	WO 96 21452 A (ADAMS JERRY LEROY ;BOEHM JEFFREY CHARLES (US); GALLAGHER TIMOTHY F) 18 July 1996 see abstract see page 37, line 4 - line 10; claims; examples ---	2,8-15
Y	WO 95 02591 A (SHELDRAKE PETER WILLIAM ;ADAMS JERRY LEROY (US); BOEHM JEFFREY CHA) 26 January 1995 see abstract; claims; examples ---	2,8-15
X	US 5 629 315 A (BIANCO JAMES A ET AL) 13 May 1997 see abstract see column 9, line 53 - line 55; claims 1,3; examples 3,7 ---	1,3,4
X	WO 95 06031 A (IMMUNEX CORP) 2 March 1995 see abstract see page 2, line 31 - page 4, line 17 see page 6, line 19 - line 22 see claims; example 11 ---	1,3,4
X	WO 97 10712 A (MARGOLIN SOLOMON B) 27 March 1997 see abstract see page 26, line 28 - page 27, line 1; claims ---	1,7
X	WO 96 01318 A (STEENO RES GROUP AS ;GESSER BORBALA (DK); GROENHOEJ LARSEN CHRISTI) 18 January 1996 see abstract see page 1, line 1 - line 25; table 3 see claims ---	1,3,4
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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03015

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 26278 A (STEENO RES GROUP AS ;GESSER BORBALA (DK); GROENHOEJ LARSEN CHRISTI) 24 July 1997 see abstract see page 1, line 1 - line 25; claims; table 3 ---	1,3,4
X	WO 95 22546 A (CELL THERAPEUTICS INC) 24 August 1995 see abstract see page 10, line 23 - line 38; claims ---	1,3,4
A	WALKER, RICHARD F. ET AL: "Ovarian effects of an anti-inflammatory-immunomodulatory drug in the rat" TOXICOL. APPL. PHARMACOL. (1988), 94(2), 266-75 CODEN: TXAPA9;ISSN: 0041-008X, XP002094124 see the whole document -----	1-7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB 98/ 03015

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claim(s) 1-15
is(are) directed to a method of treatment of the human/animal
body, the search has been carried out and based on the alleged
effects of the compound/composition.
2. ☒ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such
an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all
searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment
of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report
covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is
restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

In view of the the large number of compounds which are theoretically contained within the definition "compound which inhibits the production, transcription or translation of a cytokine" of claim 1 and which are defined by the general formula of claim 8, the search has to be restricted on economic grounds. The search was limited to the general idea of the invention, to the compounds mentioned in claim 8 wherein R1 is 4-pyridyl or 4-pyrimidinyl and to the compound mentioned in the examples (Art.6 PCT; Guidelines Chapt.II.7 last sentence and Chapt.III,3.7).
Claim searched
 completely: 9

Claims searched incompletely:

1-8,10-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/03015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9507699 A	23-03-1995	US 5543150 A	06-08-1996
		AT 174796 T	15-01-1999
		AU 689133 B	26-03-1998
		AU 7726194 A	03-04-1995
		BR 9407475 A	12-11-1996
		CA 2171939 A	23-03-1995
		DE 69415543 D	04-02-1999
		EP 0719146 A	03-07-1996
		FI 961221 A	14-05-1996
		HU 76824 A	28-11-1997
		IL 110972 A	10-03-1998
		JP 9502724 T	18-03-1997
		LT 96027 A,B	25-07-1996
		LV 11527 A	20-10-1996
		LV 11527 B	20-02-1997
		NO 961044 A	14-05-1996
		ZA 9407073 A	02-05-1995
WO 9725045 A	17-07-1997	AU 1577497 A	01-08-1997
		CA 2242327 A	17-07-1997
		NO 983189 A	10-09-1998
		PL 327735 A	21-12-1998
WO 9640143 A	19-12-1996	AU 699646 B	10-12-1998
		AU 6272696 A	30-12-1996
		CA 2223533 A	19-12-1996
		CN 1192147 A	02-09-1998
		CZ 9703925 A	16-09-1998
		EP 0831830 A	01-04-1998
		NO 975716 A	04-02-1998
		PL 323916 A	27-04-1998
		US 5658903 A	19-08-1997
		US 5739143 A	14-04-1998
WO 9621654 A	18-07-1996	AU 4770496 A	31-07-1996
		BR 9607097 A	11-11-1997
		CA 2210322 A	18-07-1996
		CZ 9702195 A	18-03-1998
		EP 0802908 A	29-10-1997
		FI 972970 A	11-09-1997
		JP 10512264 T	24-11-1998
		NO 973231 A	11-09-1997
		PL 321292 A	24-11-1997
WO 9621452 A	18-07-1996	US 5593992 A	14-01-1997
		AU 4657296 A	31-07-1996
		BG 101727 A	31-03-1998
		BR 9606904 A	21-10-1997
		CA 2209938 A	18-07-1996
		CN 1177299 A	25-03-1998
		CZ 9702158 A	15-04-1998
		EP 0809499 A	03-12-1997
		FI 972901 A	08-09-1997
		JP 10512555 T	02-12-1998
		NO 973167 A	08-09-1997
		PL 322249 A	19-01-1998
		SK 90297 A	14-01-1997
		US 5670527 A	23-09-1997

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/03015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9621452 A		US 5593991 A	14-01-1997
		US 5663334 A	02-09-1997
		ZA 9600094 A	24-07-1996
WO 9502591 A	26-01-1995	AP 484 A	23-04-1996
		AU 7185098 A	27-08-1998
		AU 694130 B	16-07-1998
		AU 7335494 A	13-02-1995
		BR 9407079 A	27-08-1996
		CA 2167311 A	26-01-1995
		CN 1129447 A	21-08-1996
		CZ 9600119 A	16-10-1996
		EP 0708768 A	01-05-1996
		FI 960177 A	15-01-1996
		HU 75313 A	28-05-1997
		JP 9500137 T	07-01-1997
		NO 960173 A	15-01-1996
		NZ 269457 A	26-08-1998
		PL 312614 A	29-04-1996
		SG 52368 A	28-09-1998
		SK 4796 A	08-01-1997
		US 5593992 A	14-01-1997
		US 5670527 A	23-09-1997
		US 5593991 A	14-01-1997
		US 5663334 A	02-09-1997
		ZA 9405193 A	20-04-1995
US 5629315 A	13-05-1997	US 5652243 A	29-07-1997
		US 5648357 A	15-07-1997
		US 5621102 A	15-04-1997
		US 5620984 A	15-04-1997
		US 5580873 A	03-12-1996
		US 5612349 A	18-03-1997
		US 5567704 A	22-10-1996
		US 5580874 A	03-12-1996
		US 5739138 A	14-04-1998
		US 5792772 A	11-08-1997
		AU 669702 B	20-06-1996
		CA 2112239 A	16-09-1993
		CN 1085557 A, B	20-04-1994
		CZ 9402123 A	13-09-1995
		EP 0584347 A	02-03-1994
		JP 8259565 A	08-10-1996
		JP 2753395 B	20-05-1998
		JP 6509584 T	27-10-1994
		NO 943263 A	02-11-1994
		NZ 247038 A	24-02-1995
		WO 9317684 A	16-09-1993
		ZA 9301542 A	27-09-1993
WO 9506031 A	02-03-1995	AU 5030298 A	05-03-1998
		AU 687436 B	26-02-1998
		AU 7569494 A	21-03-1995
		EP 0715619 A	12-06-1996
		FI 960803 A	22-04-1996
		JP 9503201 T	31-03-1997
		NO 960723 A	23-02-1996
		NZ 271893 A	24-11-1997

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/03015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9506031 A		US 5594106 A	14-01-1997
		US 5629285 A	13-05-1997
WO 9710712 A	27-03-1997	AU 7239996 A	09-04-1997
		CA 2232191 A	27-03-1997
		EP 0866656 A	30-09-1998
WO 9601318 A	18-01-1996	AU 686816 B	12-02-1998
		AU 2612195 A	25-01-1996
		BR 9508243 A	21-10-1997
		CA 2194444 A	18-01-1996
		CN 1159830 A	17-09-1997
		CZ 9700014 A	14-05-1997
		EP 0769054 A	23-04-1997
		FI 970009 A	04-03-1997
		HU 76673 A	28-10-1997
		JP 10502249 T	03-03-1998
		NO 970020 A	05-03-1997
		NZ 287406 A	28-07-1998
		PL 319429 A	04-08-1997
		SK 161496 A	06-08-1997
WO 9726278 A	24-07-1997	AU 1301197 A	11-08-1997
		AU 4385696 A	11-08-1997
		CA 2243275 A	24-07-1997
		WO 9726279 A	24-07-1997
		EP 0879245 A	25-11-1998
WO 9522546 A	24-08-1995	AU 1967495 A	04-09-1995
		CA 2183562 A	24-08-1995
		EP 0746557 A	11-12-1996
		JP 9511496 T	18-11-1997
		US 5807862 A	15-09-1998

Synthesis and Properties of Fluorescent NF- κ B-Recognizing Hairpin Oligodeoxyribonucleotide Decoys

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Intramolecular fluorescence quenching of cyanine dyes was investigated using a model hairpin oligonucleotide decoy encoding a NF- κ B p50 subunit binding site. Two types of hairpin oligonucleotides were synthesized: (1) 5'-(6-aminoethyl)- and 3'-(3-aminopropyl)-linked (**I**); (2) 5'-(6-aminoethyl)- and 3'-[3-(3-hydroxypropylthio)propyl]-linked (**II**). Oligonucleotide **I** was covalently modified using monofunctional either Cy3- or Cy5.5-*N*-hydroxysuccinimide esters. Using reverse-phase HPLC, mono- and dicyanineamide derivatives of **I** were isolated. Mono-Cy3-modified derivatives of **I**, but not the mono-Cy5.5-modified derivatives, showed a 2-fold higher Cy3 fluorescence intensity compared to the free dye. There was no detectable difference in fluorescence between the di-Cy3 derivative of **I** and the free dye at the same concentration. However, there was a 4-fold quenching of fluorescence in the case of the di-Cy5.5 derivative of the same hairpin oligonucleotide. The quenching of Cy5.5 fluorescence could not be explained by the interaction of Cy5.5 with nucleotide bases as demonstrated by incubating free Cy5.5 dye with oligonucleotides. The quenching effect was further investigated using an oligonucleotide bearing a cleavable 3'-amino-terminated linker bearing an S–S bond (**III**). After modification of the 5'- and 3'-end of oligonucleotide **III** with a Cy5.5 monofunctional hydroxysuccinimide ester, a 70–75% quenching of fluorescence was observed. Fluorescence was 100% dequenched after the reduction of S–S bond. The obtained result unequivocally demonstrates that the formation of intramolecular Cy5.5 dimers is the dominant mechanism of fluorescence quenching in symmetric dye–dye hairpin decoy beacons.

INTRODUCTION

The ability to attenuate the level of target gene expression in living cells allows individual biochemical pathways to be dissected (1) as well as alteration of the phenotype and, potentially, enables the attenuation of gene expression in vivo (2–6). The “knockdown” of gene expression could be achieved at transcription and post-transcription. In the first case, oligonucleotide hairpin decoys could be used (reviewed in ref 7). In the second case, siRNA (small interfering) (8, 9) and antisense oligonucleotides have been proven to be effective. The inhibitive effect of both DNA-based and RNA-based constructs depends to a large extent on their ability to penetrate into the cellular interior and on the rate of intracellular catabolism of short oligo deoxy- or ribonucleotides. Both endo- and exonuclease degradation severely limits the half-life of oligodeoxyribo- or oligoribonucleotides in vitro and in vivo. Nevertheless, the stability of oligonucleotides can be modified by applying a variety of synthetic strategies (10, 11), reviewed in refs 12–14). While recent research has proved that antisense oligoribonucleotides (especially siRNAs) are undoubtedly efficacious in vitro, they are susceptible to rapid degradation prior to interaction with target mRNA in vivo (15). Small interfering RNAs are also known to activate

interferon-mediated pathways resulting in a broad interferon-mediated gene upregulation (16, 17).

Hairpin oligonucleotide decoys are designed to block the transcription of a target gene by competing with genomic DNA for relevant transcription factors. For example, decoys bearing a NF- κ B recognition sequence, which binds the p50 subunit of a transcription factor, were amenable to modifications with reactive nucleotide analogues that enabled trapping of NF- κ B on the decoy and resulted in apoptosis (18–20). To assess the efficacy of intracellular penetration and to track their intracellular fate, oligonucleotides can be labeled with molecular probes to make them detectable by imaging techniques, either microscopic, or macroscopic for in vivo work (21–24). The goal of this work was to synthesize and characterize far-red fluorochrome-labeled decoys. Indocyanine far red fluorescent dyes have excellent photostability, are pH insensitive, and potentially could be detected in vivo. We anticipate that such labeled oligonucleotides will prove useful in elucidating mechanisms of hairpin decoy penetration into cells and imaging interactions between the decoy and target transcription activators.

MATERIALS AND METHODS

Materials. Oligodeoxyribonucleotides with 3',5'-diaminoalkyl linkers were synthesized at MGH Department of Molecular Biology, DNA Oligonucleotide Synthesis Core (Dr. Jay Klaren) and supplied in ammonia solution.

Triethylammonium acetate solution (2 M, TEAA), pH 7.0, was purchased from Glen Research (Sterling VA), 2-aminoethyl-2'-aminoethanethiosulfonate from Pierce-

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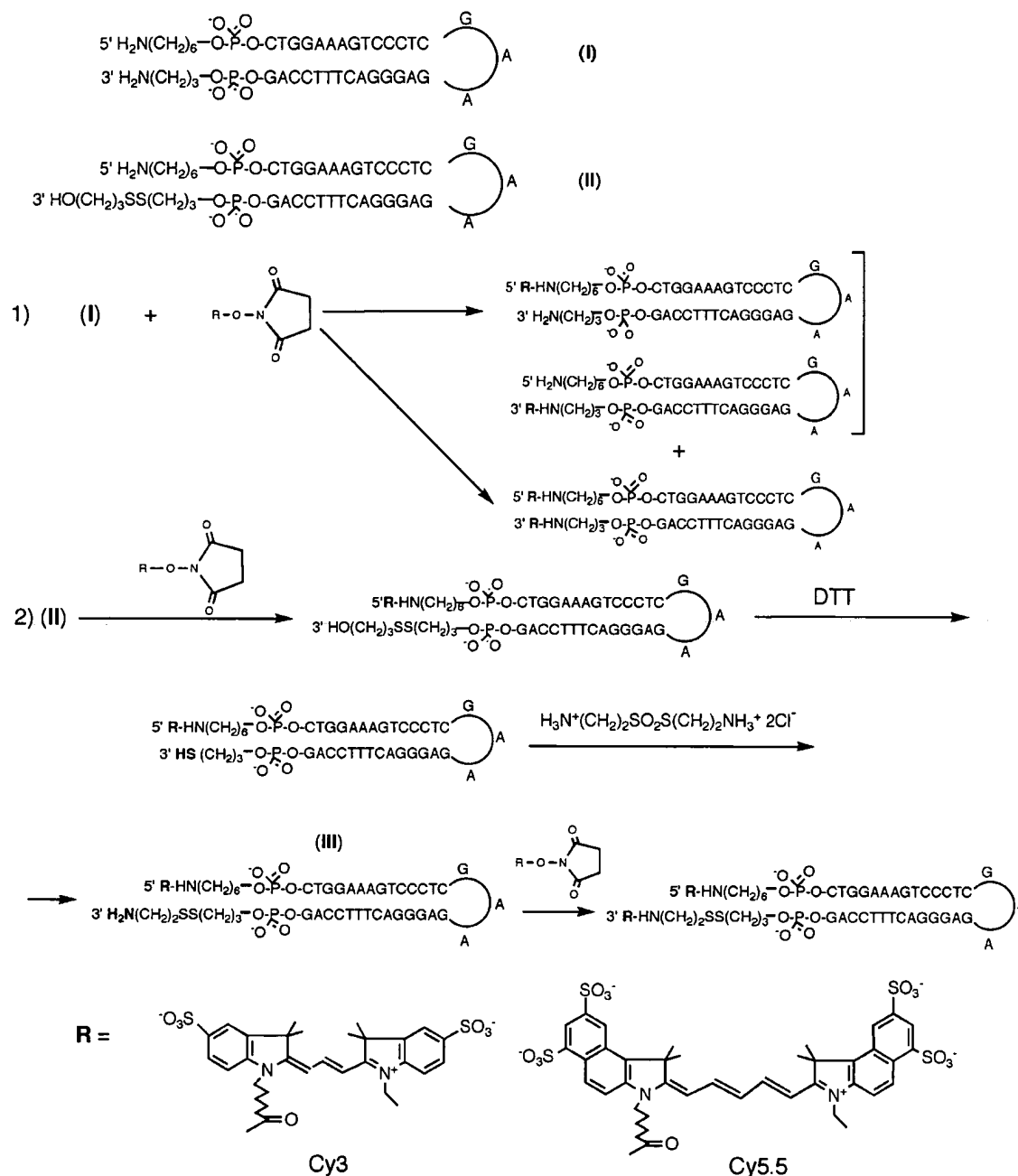


Figure 1. Scheme of fluorescently labeled hairpin oligonucleotide decoy synthesis. **I**, precursor (noncleavable, diamino terminated) oligonucleotide; **II**, oligonucleotide with a 3'-dithio linker; **III**, monomodified oligonucleotide with an amino-terminated dithio linker.

Endogen (Rockford, IL), Cy5.5 mono-*N*-hydroxysuccinimide ester (NHS) and Cy3 NHS from Amersham Biosciences (Piscataway, NJ). Micro Bio-Spin 6 columns (SSC buffer, pH 7.0) were obtained from Bio-Rad (Hercules CA). All other chemicals were from Sigma-Aldrich (St. Louis, MO).

Initial Purification of Oligonucleotides. The ion-pair reversed-phase HPLC method was used for the isolation and purification of modified oligodeoxyribonucleotides on a C18 column (Zorbax ODS 4.6 × 25 mm, DuPont). For HPLC linear gradient the following buffers were used: A, 2% acetonitrile in 0.1 M TEAA, pH 7; B, 50% acetonitrile in 0.1 M TEAA, pH 7. The column was eluted at 1 mL/min at room temperature. Purified oligonucleotides were concentrated in a centrifugal vacuum concentrator (SpeedVac, Savant).

Modification of Oligodeoxyribonucleotides Bearing 3'- and 5'-Aminoalkyl Linkers (Figure 1, Reaction 1). Ten nanomoles of the oligonucleotide d(pCTG-GAAAGTCCCTCGAAGAGGGACTTTCCAGp) bearing 3'- and 5'-aminoalkyl linkers was dissolved in 15 μ L of 0.1 M NaHCO₃. To this was added 7 μ L of 62 mM Cy3-NHS (or 49 mM Cy5.5-NHS in DMSO), and the mixture was incubated at room temperature for 6–16 h in the dark. Then 40 μ L of water was added, and the modified oligonucleotide was separated from excess dye by two consecutive separations on Micro Bio-Spin 6 columns according to the manufacturer's recommendations. After the second spin-chromatography, oligonucleotides were precipitated by standard ethanol–sodium acetate treatment and purified by HPLC as described above. The chromatography showed complete absence of free dyes

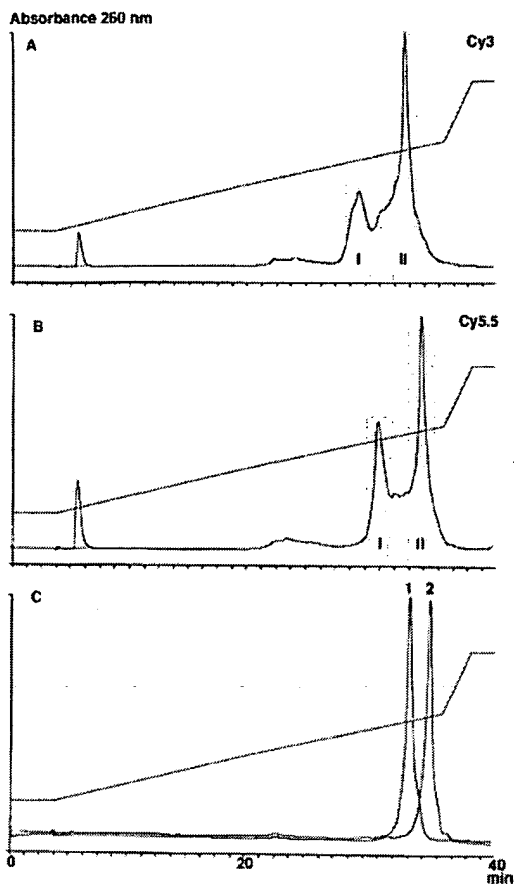


Figure 2. Preparative HPLC of Cy3 (A) and Cy5.5 (B) modified oligonucleotide **I**. Shaded peaks corresponding to mono (**I**) and di- (**II**)- modified oligonucleotides were collected for further analysis; (C) superimposed elution profiles of purified dicyanine-modified oligonucleotides: 1, Cy3-modified; 2, Cy5.5-modified oligonucleotide **I**.

and a disappearance of the peak corresponding to the nonlabeled oligonucleotide. Fractions corresponding to mono- and dimodified oligonucleotides were collected (Figure 2) and concentrated by evaporation using a centrifugal vacuum concentrator (final volume about 50–100 μ L). Oligonucleotides were precipitated in ethanol–sodium acetate by adding a 0.1 volume of 3 M sodium acetate, pH 5.5, followed by 5 volumes of cold ethanol. Labeled oligonucleotides were characterized using MALDI-mass spectrometry (Integrated DNA Technologies, Coralville, IA) and yielded for di-Cy3-labeled (**I**) ($M + H^+$) 11195.8 (calculated, 11207.0) and for di-Cy5.5 labeled (**I**) ($M + H^+$) 11775.1 (calculated, 11796.5). In calculations we assumed that acetate anion served as a counterion of the quarternized nitrogen in Cy dye residues.

Synthesis of Fluorescent Oligonucleotide Decoy Probes Bearing a Dithio Bond (Figure 1, Reaction 2). The initial compound used for the synthesis of dual-labeled probes was 5'-N-MeOTr-**II**, i.e. oligonucleotide d(pCTGGAAAGTCCCTCGAAGAGGGACTTTCCAGp) bearing asymmetric 5'-(6-MeOTr-aminoethyl)- and 3'-[3-(3-hydroxypropyldithio)propyl] linkers (Figure 1). 5'-N-MeOTr-**II** was purified by HPLC on an octadecyl silica column (Zorbax ODS 5 μ m, DuPont) using a linear gradient of buffers A and B (10–100% B, 30 min) and was detritylated using 80% acetic acid for 1 h. Further synthesis included the following steps: (1) reacting the purified oligonucleotide with NHS esters of Cy5.5 or Cy3 dyes as described above; (2) isolating the monolabeled

oligonucleotide on the HPLC column and reducing the 3'-disulfide bond with dithiotreitol, resulting in the formation of an oligonucleotide bearing a 3'-(3-mercaptopropyl) linker. Briefly, 10 μ L of 1 M DTT was added to the monolabeled oligonucleotide dissolved in 100 μ L of 0.02 M NaHCO_3 . After a 1 h incubation at room temperature, the reduced oligonucleotide was precipitated by using ethanol–sodium acetate treatment; (3) reacting the above oligonucleotide with 2-aminoethyl-2'-aminoethane thiosulfonate. The reaction yielded oligonucleotide **III**, containing a 3'-[3-(2-aminoethyldithio)propyl] linker (Figure 1). Briefly, the oligonucleotide was dissolved in 50 μ L of 0.2 M NaHCO_3 , the solution was cooled to 4 $^\circ\text{C}$, mixed with 15 μ L of 0.15 M 2-aminoethyl-2'-aminoethanethiosulfonate and incubated for 1 h at 4 $^\circ\text{C}$ followed by separation on a Micro Bio-Spin 6 column; (4) modifying oligonucleotide **III** with an *N*-hydroxysuccinimide ester of the reporter dye (Cy5.5 or Cy3); (5) isolating dual-labeled oligonucleotide by HPLC. Oligonucleotides were precipitated by adding 2% lithium perchlorate in acetone and redissolved in water. By MALDI-mass spectrometry the ($M + H^+$) was 11905.6 (calculated – 11893.8).

Interaction of Hydrolyzed Cyanine NHS-esters with Oligonucleotide Containing 3',5'-Diaminoalkyl Linkers. Three nanomoles of the oligonucleotide was dissolved in 25 μ L of solution containing hydrolyzed Cy5.5-NHS, and the resulting mixture was incubated at the same conditions as the standard Cy5.5-NHS oligonucleotide reaction mixture. To obtain hydrolyzed Cy5.5-NHS ester, 7 μ L of 49 mM Cy5.5-NHS in DMSO was dissolved in 18 μ L of 0.2 M NaHCO_3 , and the mixture was incubated for 36 h in the dark at room temperature.

Interaction of Hydrolyzed Cy5.5 NHS with DTT or Glutathione. To 35 μ L of hydrolyzed Cy5.5 were added 10 μ L of 1 M DTT (or 0.5 M reduced glutathione) and 10 μ L, 0.2 M NaHCO_3 , and the solution was incubated in the dark overnight.

The Reduction of Disulfide Bond in Dual-Labeled Oligonucleotides. To reduce the dithio bond in the oligonucleotide and to achieve dequenching of fluorescence, dual-labeled probes were diluted in 1–1.5 mL of PBS buffer (pH 7.5) and subjected to fluorimetry, followed by mixing with 15 μ L of 1 M DTT or with 30 μ L of 0.5 M reduced glutathione. The solutions were incubated overnight at room temperature followed by fluorimetry as described above.

DNase Digestion of Labeled Probes. Solutions of the oligonucleotides were prepared in magnesium-containing Dulbecco's PBS, pH 7, at the concentration of 20–100 μM . Each solution was divided into aliquots. For each oligonucleotide, a half of the samples was treated with DNase I (10 U/mL, Stratagene, La Jolla CA) for 6 h at 37 $^\circ\text{C}$. Control samples were not treated with DNase. Absorbance and fluorescence at appropriate wavelengths were measured in DNase-treated samples and compared to the control samples.

Spectral measurements were performed at room temperature using a U-3000 and F-4500 Hitachi spectrophotometer and spectrofluorometer, respectively. The cyanine dyes and labeled oligonucleotides were diluted in 2 mL of PBS, pH 7.5, and absorbance and fluorescence spectra were recorded sequentially in quartz cuvettes.

RESULTS AND DISCUSSION

Tagging oligonucleotides with imaging probes provides a means of tracking these molecules in living cells and ultimately in vivo. For example, labeling of oligonucle-

otides with radioactive isotopes has been used for non-invasive tracking of oligonucleotide biodistribution. This approach potentially enables localizing sites of target gene expression (reviewed in (25, 26)). Conjugation of oligonucleotides with cyanine dyes could result in highly useful "beacons" based on the effect of fluorescence quenching between the labeled proximal 3'- and 5'-termini. The quenching effect is abrogated by the de-quenching of fluorescence upon the interaction with *in vitro* targets in structurally constrained stem-loop beacons as well as stemless beacons (reviewed in 27, 28). Moreover, it has been demonstrated that enzyme-specific dequenching of cyanine-labeled macromolecules can be imaged *in vivo* (29). In this report we investigated quenching and dequenching effect in hairpin oligonucleotide decoys using two commercially available cyanine dyes.

Purification of Initial Oligonucleotides. To obtain a first generation of quenched oligonucleotide decoy probes, we used d(pCTGGAAAGTCCCTCGAAGAGG-GACTTTCAGp) as a precursor for synthesis of dye-labeled probes. This oligonucleotide was prepared to enable asymmetric modifications at the 3'- and 5'-termini using a protected 5'-(6-MeOTr-aminoethyl)-linker as well as a free amino group-containing 3'-(3-aminopropyl) linker (Figure 1). We assumed that above linkers would provide a means of conjugating the first dye (reporter or quencher) specifically to the 3'-amino group. The synthesis would be followed by (1) the isolation of the 3' mono Cy-dye labeled 5'-N-MeOTr-I fraction by HPLC; (2) detritylation of I by 80% acetic acid. Deprotected compound would then be used to attach the second dye (quencher or reporter) to the free 5'-amino group followed by HPLC purification. Contrary to our expectations, we found that the 5'-MeOTr-NH bond is unstable and hydrolyzes rapidly during the purification of I by HPLC in 0.1 M TEAA, pH 7.0, or by using the Poly-Pack cartridge method. Since partial (10–30%) detritylation of the 5'-amino group took place, oligonucleotide I could not be used for synthesis of probes dually labeled by two different dyes. Therefore, after HPLC isolation from the reaction mixture, oligonucleotide I was detritylated by 80% acetic acid, and the obtained oligonucleotide (HPLC elution time, 18.5 min) was used to synthesize probes dually labeled by Cy3 or Cy5.5 cyanine dyes.

Purification of dye-modified oligonucleotides from nonreacted dyes was attempted using three approaches: (a) by repeated ethanol–sodium acetate precipitation of oligonucleotide; (b) by gel filtration on NAP-10 cartridges; (c) by separating on Micro Bio-Spin 6 columns. We found that the particular dyes and oligonucleotides used in this work could not be efficiently separated using size-exclusion chromatography on a Sephadex G-25 column (NAP-10). A procedure involving separations on Micro Bio-Spin 6 columns followed by ethanol–sodium acetate precipitation of the oligonucleotides was clearly superior over other purification strategies. The mono- and dimodified derivatives could then be easily separated using a C18 HPLC column (Figure 2 (A,B, peaks I and II)). The isolated fluorescent dimodified oligonucleotides showed a very high purity (Figure 2, C) suitable for further spectral analysis and mass-spectrometry. Elution times on HPLC column were 27.0 min for the di-Cy3-modified oligonucleotide and 28.3 min for the di-Cy5.5-modified one.

Spectral Properties of Modified Oligonucleotide

I. To investigate spectral properties of cyanine dye-modified oligonucleotides, we initially performed a modification of hairpin oligonucleotide I with Cy3-NHS and

Cy5.5-NHS followed by the isolation of mono- and dicyanine derivatives of I using HPLC. The above dyes were chosen because of the advantageous photostability of Cy3 and the near-infrared "in vivo imaging" fluorescence range of Cy5.5 (29, 30). The initial experiments showed that the attachment of dyes to hairpin oligodeoxyribonucleotides with 3'-(3-aminopropyl), 5'-(6-aminoethyl)-linkers resulted in significant changes in the visible range of cyanine dye absorption when spectra of nonconjugated dyes were compared to the cyanine-modified oligonucleotides. First, we observed an increase of absorbance in the range of 500–525 nm in the case of Cy3 (Figure 3A) and in the range of 600–650 nm in the case of Cy5.5 after the conjugation (Figure 3B). Such spectral changes were previously attributed to a formation of dimers in Cy-modified proteins (31). In our case, such spectral changes were detectable only in the case of dimodified oligonucleotides as opposed to its mono-Cy derivative. There was no evidence of the formation of J-aggregates that absorb light at longer wavelengths. The increase of absorption at shorter wavelengths was especially prominent in the case of Cy5.5 and was less prominent for Cy3 derivatives (Figure 3). In addition, there was a small but detectable 3–5 nm "red" shift of the fluorescence emission maximum. We also observed that covalent linking of a single Cy3 group to I causes a 100% increase of the fluorescence intensity. In the case of Cy5.5 fluorescence in the mono-derivatized oligonucleotide did not change appreciably whereas dimodified I showed a substantial quenching of Cy5.5 fluorescence which could be reliably measured using extensive enzymatic degradation of the oligonucleotide. As a result of DNase-mediated cleavage, fluorescence increased approximately 13 times. Additional control experiments that included incubating hydrolyzed cyanine dye esters with the oligonucleotide showed that the above fluorescence effects were specific for conjugated dyes and could not be explained by simple interaction of cyanine moiety with nucleotides (e.g. partial intercalation of cyanine group between the nucleotide pairs).

Experiments with Derivatives of Oligonucleotide II Containing a Cleavable Bond. To prove that the observed self-quenching effects were caused by the interaction of two cyanine dye residues positioned in close proximity to each other (i.e. that hairpin conformation induces the dimerization of Cy5.5 dye), we designed a hairpin oligonucleotide II (HPLC elution time, 19.1 min) with a nucleotide sequence identical to that of I but containing a dithio bond at the 3'-terminus of the molecule (Figure 1). We hypothesized that the bond could be reduced and that the formed 3'-sulfhydryl could then react with 2-aminoethyl-2'-aminoethanethiosulfonate to form a 3'-amino linker bearing a dithio bond. The amino group could be then used for further modification of II with a second fluorophore or other probe to yield oligonucleotide III (Figure 2, HPLC elution time, 28.0 min). In oligonucleotide III that bears two Cy5.5 modifications, the 3'-dithio bond could be reduced using a 10–15 mM dithiotreitol (or glutathione). First, we excluded potential quenching of Cy dyes as a result of chemical interaction with DTT or glutathione. Second, we tested whether the reduction that cleaves the S–S bond results in the dissociation of the dimer and resultant dequenching of fluorescence. As expected, after DTT or glutathione treatment, we observed a change in absorbance in the range of 600–650 nm (Figure 4 A) and a dequenching of the Cy5.5 fluorescence (Figure 4B and 4C). The ratio of fluorescence intensities measured after and before the treatment with DTT was in the range of 3.5 to 4. The latter quenching factor was close to that measured using

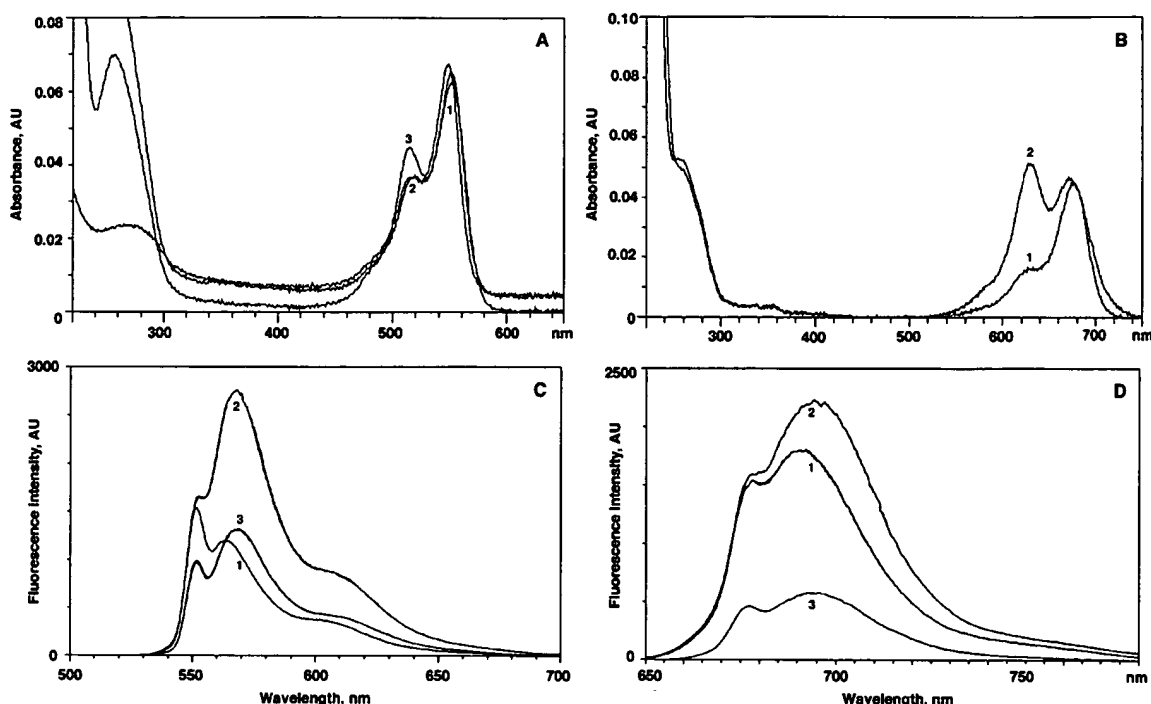


Figure 3. (A) Absorption and (C) emission spectra of 1, Cy3 dye; 2, mono-Cy3 derivative; and 3, di-Cy3 derivative of oligonucleotide I. (B) Absorption spectra of 1, mono-Cy5.5; 2, di-Cy5.5 derivative of oligonucleotide I. (D) Emission spectra of 1, Cy5.5; 2, mono-Cy5.5 derivative of oligonucleotide I. The spectrum of di-Cy5.5 oligonucleotide I shows strong absorption at 629 nm due to the dye dimerization and no absorption due to J-aggregates.

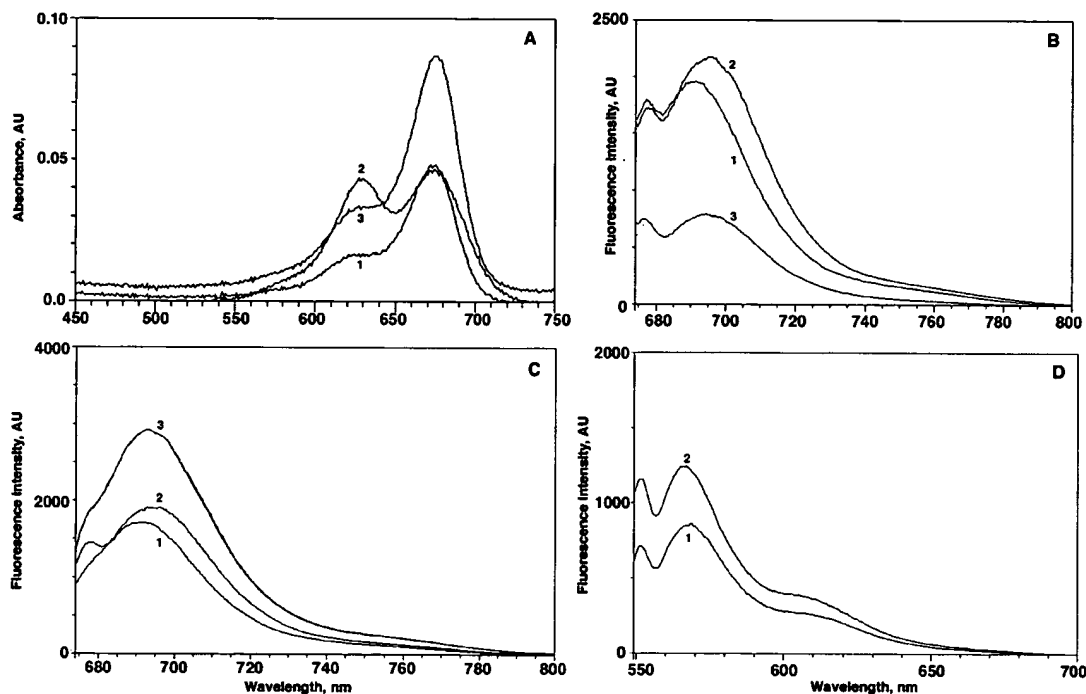


Figure 4. (A) Absorption spectra: 1, Cy5.5 in PBS; 2, dimodified oligonucleotide III before disulfide bond reduction with DTT; 3, after DTT treatment. (B) Emission spectra before DTT treatment: 1, Cy5.5; 2, mono-Cy5.5-modified oligonucleotide III; 3, di-Cy5.5-modified oligonucleotide III. (C) Emission spectra after disulfide bond reduction with DTT: 1, Cy5.5; 2, mono-Cy5.5-modified oligonucleotide III; 3, di-Cy5.5-modified oligonucleotide III. (D) Emission spectra of di-Cy3-modified oligonucleotide III: 1, before; 2, after DTT treatment.

extensive DNase I-mediated degradation (5.4 times, Table 1). The absorbance spectrum reverted to the typical Cy5.5 shape following the reduction with a concomitant 1.8-fold increase at the maximum of absorbance because of the transition of 50% of the dimerized, blue-shifted

Cy5.5 molecules into the noninteracting pool of molecules. Interestingly, dye quenching in non-DTT-cleavable di-Cy5.5 decoy was more efficient than that of in a cleavable one (Table 1). The observed difference in quenching factors (12.9 for 3'-Cy5.5-I-5'-Cy5.5 vs 5.6 for 3'-Cy5.5-

Table 1. Some Fluorescent Properties of Cyanine Dyes and Labeled Oligonucleotide Hairpin Probes

fluorophore/labeled oligonucleotide	excitation, nm	emission max., nm	quenching factor ^a
Cy3	548	563	1.0
Cy5.5	674	692	1.0
Cy3-I	548	568	~ ^b
Cy3-I-Cy3	548	568	5.4
Cy5.5-I	674	695	1.1
Cy5.5-I-Cy5.5	674	695	12.9
Cy3-II	548	568	ND ^c
Cy3-III-Cy3	548	567	ND
Cy5.5-II	674	695	1.2
Cy5.5-III-Cy5.5	674	695	5.6

^a Quenching factor was calculated as a ratio of fluorescence intensities measured in a sample containing 20–100 μ M of labeled hairpin oligonucleotide decoy without DNase I to that of containing DNase I. ^b Fluorescence of oligonucleotide-conjugated Cy3 was higher than that of the free Cy3 by a factor of 2. ^c ND, not done.

III-5'-Cy5.5, Table 1) could be a result of differences in both linker length and structure in above constructs. Alternatively, thiol–disulfide exchange catalyzed by minute amounts of free thiols in oligonucleotide III dimodified preparation could result in partial dequenching of Cy5.5 dye.

The DTT treatment of di-Cy3-modified oligonucleotide lead only to a modest increase of fluorescence (1.4 times, Figure 4D). However, as noted before, in the case of Cy3 it is problematic to estimate the degree of true quenching of Cy3 conjugated to a hairpin nucleotide since the monomodified Cy3-oligonucleotide had higher fluorescence than free Cy3 dye at the same molar concentration (see Figure 4C). In the case of a monomodified oligonucleotide (i.e. Cy3-NH-oligonucleotide-S-S-CH₂CH₂-CH₂OH) disulfide reduction did not result in any appreciable changes of probe fluorescence (not shown).

In conclusion, we synthesized and tested fluorescent hairpin oligonucleotides bearing one or two fluorophores at their termini. Our results demonstrate that (1) there is a dimerization of cyanine dyes both in the case of dimodified Cy5.5 and dimodified Cy3-labeled oligonucleotides, (2) dimerization of the Cy5.5 fluorophore results in strong self-quenching, and (3) fluorescence quenching in dimodified Cy5.5 oligonucleotides could be reversed by dissociating one of the linkers between the oligonucleotide and one of the dyes. The observed effects and developed synthetic approaches are instrumental in further design of hairpin oligonucleotide beacons that would have reversible, quenched near-infrared fluorescence. We are currently refining the developed synthetic strategy for achieving highly termini-specific labeling with fluorescent probes and fluorescence quenchers.

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LITERATURE CITED

- (1) Xu, J., Wu, Y., He, L., Yang, Y., Moore, S. A., and Hsu, C. Y. (1997) Regulation of cytokine-induced iNOS expression by a hairpin oligonucleotide in murine cerebral endothelial cells. *Biochem. Biophys. Res. Commun.* 235, 394–397.
- (2) Nakamura, T., Morishita, R., Asai, T., Tsuboniwa, N., Aoki, M., Sakonjo, H., Yamasaki, K., Hashiya, N., Kaneda, Y., and Ogiwara, T. (2002) Molecular strategy using cis-element 'decoy' of E2F binding site inhibits neointimal formation in

porcine balloon-injured coronary artery model. *Gene Ther.* 9, 488–494.

- (3) Kume, M., Komori, K., Matsumoto, T., Onohara, T., Takeuchi, K., Yonemitsu, Y., and Sugimachi, K. (2002) Administration of a decoy against the activator protein-1 binding site suppresses neointimal thickening in rabbit balloon-injured arteries. *Circulation* 105, 1226–1232.
- (4) Buchwald, A. B., Wagner, A. H., Webel, C., and Hecker, M. (2002) Decoy oligodeoxynucleotide against activator protein-1 reduces neointimal proliferation after coronary angioplasty in hypercholesterolemic minipigs. *J. Am. Coll. Cardiol.* 39, 732–738.
- (5) Novina, C. D., Murray, M. F., Dykxhoorn, D. M., Beresford, P. J., Riess, J., Lee, S. K., Collman, R. G., Lieberman, J., Shankar, P., and Sharp, P. A. (2002) siRNA-directed inhibition of HIV-1 infection. *Nat. Med.* 8, 681–686.
- (6) Cullen, B. R. (2002) RNA interference: antiviral defense and genetic tool. *Nat. Immunol.* 3, 597–599.
- (7) Cho-Chung, Y. S., Park, Y. G., and Lee, Y. N. (1999) Oligonucleotides as transcription factor decoys. *Curr. Opin. Mol. Ther.* 1, 386–392.
- (8) Xia, H., Mao, Q., Paulson, H. L., and Davidson, B. L. (2002) siRNA-mediated gene silencing in vitro and in vivo. *Nat. Biotechnol.* 20, 1006–1010.
- (9) Lewis, D. L., Hagstrom, J. E., Loomis, A. G., Wolff, J. A., and Herweijer, H. (2002) Efficient delivery of siRNA for inhibition of gene expression in postnatal mice. *Nat. Genet.* 32, 107–108.
- (10) Rapaport, E., Levina, A., Metelev, V., and Zamecnik, P. C. (1996) Antimycobacterial activities of antisense oligodeoxynucleotide phosphorothioates in drug-resistant strains. *Proc. Natl. Acad. Sci. U.S.A.* 93, 709–713.
- (11) Barker, R. H., Jr., Metelev, V., Rapaport, E., and Zamecnik, P. (1996) Inhibition of Plasmodium falciparum malaria using antisense oligodeoxynucleotides. *Proc. Natl. Acad. Sci. U.S.A.* 93, 514–518.
- (12) Alama, A., Barbieri, F., Cagnoli, M., and Schettini, G. (1997) Antisense oligonucleotides as therapeutic agents. *Pharmacol. Res.* 36, 171–178.
- (13) Agrawal, S., and Iyer, R. P. (1997) Perspectives in antisense therapeutics. *Pharmacol. Ther.* 76, 151–160.
- (14) Nielsen, P. E. (1999) Peptide nucleic acids as therapeutic agents. *Curr. Opin. Struct. Biol.* 9, 353–357.
- (15) Kurreck, J. (2003) Antisense technologies. Improvement through novel chemical modifications. *Eur. J. Biochem.* 270, 1628–1644.
- (16) Bridge, A. J., Pebernard, S., Ducraux, A., Nicoulaz, A. L., and Iggo, R. (2003) Induction of an interferon response by RNAi vectors in mammalian cells. *Nat. Genet.* 34, 263–264.
- (17) Sledz, C. A., Holko, M., de Veer, M. J., Silverman, R. H., and Williams, B. R. (2003) Activation of the interferon system by short-interfering RNAs. *Nat. Cell Biol.* 5, 834–839.
- (18) Lesage, D., Metelev, V., Borisova, O., Dolinnaya, N., Oretskaya, T., Baran-Marszak, F., Taillandier, E., Raphael, M., and Fagard, R. (2003) Specific covalent binding of a NF-kappaB decoy hairpin oligonucleotide targeted to the p50 subunit and induction of apoptosis. *FEBS Lett.* 547, 115–118.
- (19) Metelev, V. G., Kubareva, E. A., Vorob'eva, O. V., Romanenkov, A. S., and Oretskaya, T. S. (2003) Specific conjugation of DNA binding proteins to DNA templates through thiol-disulfide exchange. *FEBS Lett.* 538, 48–52.
- (20) Metelev, V. G., Borisova, O. A., Volkov, E. M., Oretskaya, T. S., and Dolinnaya, N. G. (2001) New chemically reactive dsDNAs containing single internucleotide monophosphoryldithio links: reactivity of 5'-mercapto-oligodeoxyribonucleotides. *Nucl. Acids. Res.* 29, 4062–4069.
- (21) Thierry, A. R., Vives, E., Richard, J. P., Prevot, P., Martinand-Mari, C., Robbins, I., and Lebleu, B. (2003) Cellular uptake and intracellular fate of antisense oligonucleotides. *Curr. Opin. Mol. Ther.* 5, 133–138.
- (22) Hu, Q., Bally, M. B., and Madden, T. D. (2002) Subcellular trafficking of antisense oligonucleotides and down-regulation of bcl-2 gene expression in human melanoma cells using a fusogenic liposome delivery system. *Nucl. Acids. Res.* 30, 3632–3641.

- (23) Islam, A., Handley, S. L., Thompson, K. S., and Akhtar, S. (2000) Studies on uptake, sub-cellular trafficking and efflux of antisense oligodeoxynucleotides in glioma cells using self-assembling cationic lipoplexes as delivery systems. *J. Drug Target.* **7**, 373–382.
- (24) Marcusson, E. G., Bhat, B., Manoharan, M., Bennett, C. F., and Dean, N. M. (1998) Phosphorothioate oligodeoxyribonucleotides dissociate from cationic lipids before entering the nucleus. *Nucl. Acids. Res.* **26**, 2016–2023.
- (25) Hnatowich, D. J. (1996) Pharmacokinetics of ^{99m}Tc -labeled oligonucleotides. *Quart. J. Nucl. Med.* **40**, 202–208.
- (26) Tavitian, B. (2000) In vivo antisense imaging. *Quart. J. Nucl. Med.* **44**, 236–255.
- (27) Broude, N. E. (2002) Stem-loop oligonucleotides: a robust tool for molecular biology and biotechnology. *Trends Biotechnol.* **20**, 249–256.
- (28) Johansson, M. K., and Cook, R. M. (2003) Intramolecular dimers: a new design strategy for fluorescence-quenched probes. *Chemistry Eur. J.* **9**, 3466–3471.
- (29) Weissleder, R., Tung, C. H., Mahmood, U., and Bogdanov, A., Jr. (1999) In vivo imaging of tumors with protease-activated near-infrared fluorescent probes. *Nat. Biotechnol.* **17**, 375–378.
- (30) Neri, D., Carnemolla, B., Nissim, A., Leprini, A., Querze, G., Balza, E., Pini, A., Tarli, L., Halin, C., Neri, P., Zardi, L., and Winter, G. (1997) Targeting by affinity-matured recombinant antibody fragments of an angiogenesis associated fibronectin isoform. *Nat. Biotechnol.* **15**, 1271–1275.
- (31) Mujumdar, S., Mujumdar, R., Grant, C., and Waggoner, A. (1995) Cyanine-labeling reagents: sulfobenzindocyanine succinimidyl esters. *Bioconjugate Chem.* **7**, 356–362.

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